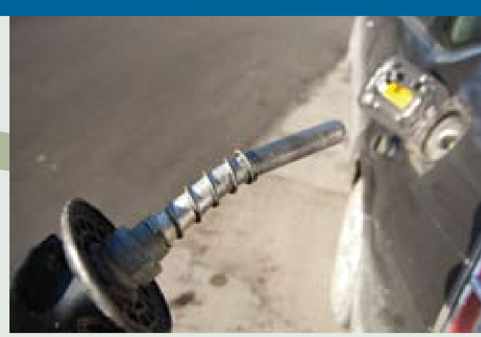
Advanced Biofuels

Task Force Report

Commonwealth of Massachusetts

Spring 2008



Acknowledgments

The Advanced Biofuels Task Force would like to thank those who contributed to the development of this report. In particular, we acknowledge the work of U.S. **Representative William Delahunt**, who has been a state and national leader on advancing the development of biofuels.

We also would like to acknowledge all those who provided oral and/or written testimony (see Appendix C for a complete list), plus the following individuals: **Shannon Ames** (staff for Senator Resor), **Kathy Baskin** (EEA), **Linda Benevides** (EEA), **Dwayne Breger** (DOER), Marc Breslow (EEA), **Ben Bunker** (DOER intern), **Lisa Capone** (EEA), **Steven Clarke** (EEA), **Brooke Coleman** (New Fuels Alliance), **Lisa Conley** (staff for Representative Smizik), **Coralie Cooper** (NESCAUM), **James Cope** (EOT), **Jennifer Crawford** (staff for Representative Dempsey), **Zachary Crowley** (staff for Representative Smizik), **Michael Ferrante** (Massachusetts Oilheat Council), **Ian Finlayson** (EEA), **John Fischer** (DEP), **David Howland** (DEP), **Chris Kealey** (MTC), **Robert Keough** (EEA), **Christine Kirby** (DEP), **Steven Larrabee** (staff for Representative Jones), **Judith Laster** (staff for Speaker DiMasi), **Michelle Manion** (NESCAUM), **Joanne McBrien** (DOER), **Patricia Moynihan** (staff for Representative Dempsey), **Sudhir Nunes** (MTC), **Christine Raisig** (MTC), **Arthur Robert** (MOBD), **Sara Schnitzer** (staff for Senator Resor), **Nancy Seidman** (DEP), **Teresa Sousa** (EEA), **Bethann Steiner** (staff for Senator Downing), **Jeannine Wheaton** (DOR), and **Christine Williams** (EOHED).

The following organizations are appreciated for their support and contributions: **Economic Development Research Group**, the **Massachusetts Technology Collaborative**, **Navigant Consulting,** and the **Northeast States for Coordinated Air Use Management**.

The Commonwealth of Massachusetts
Advanced Biofuels Task Force

April 16, 2008

Dear Governor Patrick, Senate President Murray, and Speaker DiMasi:

In November 2007, you created the Advanced Biofuels Task Force and directed us to "develop a strategic framework to accelerate the development and deployment of commercially viable advanced biofuels, and facilitate expansive biofuel research throughout the Commonwealth." We present this report to you in fulfillment of our charge.

While there are detailed findings and recommendations throughout the report, our proposals to aggressively move an advanced biofuels sector forward while maintaining high environmental standards include the following priorities:

- Prioritize efforts to achieve near-term implementation of a regional, technology-neutral and performance-based Low Carbon Fuel Standard (LCFS), with Massachusetts leading the way.
- While a Massachusetts LCFS is being developed, pass amended versions of the legislation you co-sponsored, implementing targeted transitional biofuels mandates and exempting cellulosic biofuels from the state gasoline tax, with a sunset date. Both the transitional mandates and cellulosic fuel exemption should require significant greenhouse gas reductions and other environmental protections, including direct and indirect impacts such as those on land use. The mandates and cellulosic tax exemption should be as technology-neutral as possible, and should phase out as a Low Carbon Fuel Standard comes into existence.
- Support pilot deployment in the state fleet of plug-in hybrid and all-electric vehicle technology in light- and heavy-duty vehicles, as well as fuel-efficient flex-fuel vehicles.
- Develop infrastructure necessary for consumer use of biofuels and implement limited-cost investments in equipment for ethanol and biodiesel distribution, such as E85 stations along major state highway corridors, subject to budget constraints.
- Develop standards for full lifecycle evaluation of biofuels that consider their carbon and other environmental impacts, including direct and indirect land use impacts.
- Parallel to progress on biofuels, continue to explore policy options for vehicle efficiency and reducing vehicle miles traveled.

We developed these and other recommendations outlined in the full report through a robust process of analysis and public engagement. Biofuels policy can be complicated and contentious. Nevertheless, we have arrived at a set of recommendations that allows the Commonwealth to aggressively seize the economic opportunities you foresaw, while also protecting the environment and combating climate change. It is clear to us that, with the appropriate safeguards, advanced biofuels can and should be a central part of the Commonwealth's clean energy strategy.

The potential for economic growth, environmental protection, and the improvement of our energy security is significant. Out of respect for the magnitude of this task, we held public hearings throughout the state to learn from academic institutions, communities, environmental groups and industry representatives the lessons they have learned and the wisdom they wished to pass along. This included input on research and development, production, commercialization, distribution, and utilization. We have tapped into expertise close to home and around the world, explored what other states and countries have implemented or are in the process of implementing, and reviewed the most current scientific research.

We hope that these recommendations will be of use to you in considering legislative and administrative actions to promote the development of an advanced biofuels industry in the Commonwealth. We look forward to following up with you in the coming weeks.

Sincerely,

Secretary Ian A. Bowles
Energy and Environmental Affairs
(Chair)

David W. Cash
Energy and Environmental Affairs
(Secretary's designee)

Bruce A. Jamerson
CEO, Mascoma

Colin South
President, Mascoma (designee)

David S. Davenport
Department of Revenue

Representative Bradley H. Jones, Jr.
Minority Leader

Senator Pamela P. Resor
Chair, Joint Committee on Environment,
Natural Resources and Agriculture

Senator Benjamin B. Downing
Chair, Senate Committee on Ethics and Rules

Senator Bruce E. Tarr
Assistant Minority Leader

Representative Brian S. Dempsey
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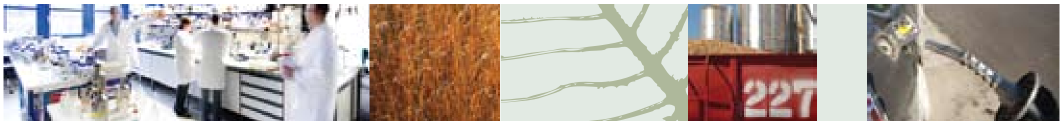
Telecommunications, Utilities, and Energy

Representative Frank I. Smizik
Chair, Joint Committee on Environment,
Natural Resources and Agriculture

Table of Contents



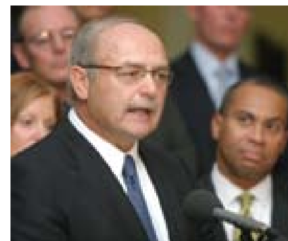
Report of the Advanced Biofuels Task Force
EXECUTIVE SUMMARY

In November 2007, the Governor, Senate President and Speaker of the House announced the creation of an Advanced Biofuels Task Force to "promote the development of an advanced biofuels industry in the Commonwealth." At that time, the price of oil was about $85 per barrel. In the five months the Task Force has been doing its work, the price has risen roughly 30%, reaching $110 per barrel. By itself, the dramatically rising cost of energy would be reason enough for Massachusetts to seek alternatives to imported fossil fuels. But there are many more reasons—the opportunity to become the global center for advanced biofuels; growth of jobs in R&D, production and commercial applications; and reduction in harmful emissions.

Governor Deval Patrick stresses the potential of Advanced Biofuels

In this context, the Task Force was charged with drafting a strategy to seize opportunities related to biofuels development and explore their economic, energy, and environmental benefits and costs. This report outlines such a strategy. It is the result of intensive work by the Task Force, legislative and executive staff, four public hearings throughout the Commonwealth, and input from academic experts as well as a wide range of industry, environmental, community, and other stakeholders.

Biofuels are substitutes for liquid petroleum fuels, including gasoline, diesel, and heating oil, that are derived from renewable organic matter and promise several advantages over fossil fuels. Petroleum products used for transportation currently contribute more than a third of greenhouse gas emissions in Massachusetts. Due to limitations in domestic supplies, reliance on petroleum makes the U.S. dependent on imports from foreign nations, many of them politically unstable. And Massachusetts, having no supplies of our own, pays high prices for imports from around the country and around the world.



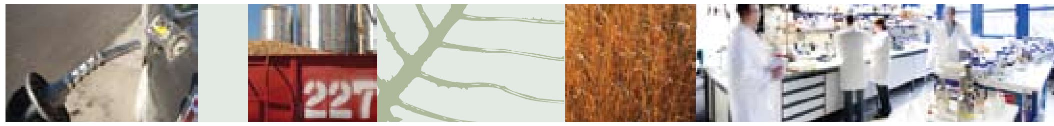
Speaker Salvatore DiMasi addresses the audience on biofuels

Advanced biofuels, which are defined in federal law as those that yield a net lifecycle reduction of at least 50% in greenhouse gas emissions compared with fossil fuels, offer particular advantages for the environment as well as the Massachusetts economy—including playing to our strengths in research and technology development and sustainable forestry.

Senate President Therese Murrray speaking at the announcement

This Executive Summary briefly reviews the main findings of the Task Force's report and provides the policy recommendations resulting from its deliberations. The report has six chapters:

Chapter 1 – The Potential Economic Opportunities of an Advanced Biofuels Sector in Massachusetts



Chapter 2 – The Energy and Environmental Lifecycle of First-Generation and Advanced Biofuels

Chapter 3 – Biofuel Feedstocks—Energy Crops, Biomass, and Waste Products

Chapter 4 – Statutory and Regulatory Mandates, Regulatory Flexibility

Chapter 5 – Promoting Infrastructure for Delivery and Distribution of Biofuels

Chapter 6 – Grants, Loans, and Tax Incentives

Chapter 1 – The Potential Economic Opportunities of an Advanced Biofuels Sector in Massachusetts

Given the state's intellectual capital and academic and laboratory resources for research and development, supporting an advanced biofuels sector offers potentially significant opportunities for economic development and job creation.

Congressman William Delahunt speaking at the announcement

In-state production of advanced biofuels derived from feedstock grown in Massachusetts could replace about 6% of our gasoline use, reducing our dependence on imported energy sources while generating jobs at home and boosting the state's growing energy sector. Biofuels have the potential to keep marginal agricultural land in production—a benefit for a state like Massachusetts, which values small-scale farming as part of its economic and physical landscape.

As an emerging technology, the economic viability of advanced biofuels still needs to be proven, however, and will depend significantly on the true extent of the greenhouse gas reductions these fuels provide.

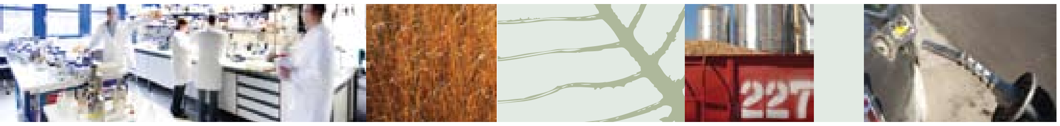
The Task Force estimates that a mature advanced biofuels industry—including technology development, feedstock cultivation, and processing into fuel—could contribute $280 million to $1 billion per year for the Massachusetts economy by 2025, while generating 1,000 to 4,000 permanent jobs and 150 to 760 temporary construction jobs. Including indirect "multiplier" effects, we estimate the permanent gains as $550 million to $2 billion and 2,500 to 9,800 jobs.

Chapter 2 - The Energy and Environmental Lifecycle of First-Generation and Advanced Biofuels

Depending on the feedstocks utilized (corn, soybeans, waste oil, switchgrass, tree trimmings, the organic portions of municipal solid waste), the energy source used to convert the feedstocks (coal, natural gas, renewables), and the land on which the feedstocks are grown (land already in production, forests or grasslands converted to croplands), biofuels can either reduce or increase greenhouse gas emissions relative to fossil fuels.

Without considering indirect impacts from changes in land use, corn ethanol could reduce greenhouse gases by approximately 20% relative to petroleum, possibly more if production processes are improved. Soybean-based biodiesel gets much better initial reviews, with greenhouse gas benefits estimated to be in the 70% range.

But recent research finds that it is critical to take land use changes into account. Shifting a substantial part of the world's food supply to fuel production is likely to cause forests and grasslands to be converted to crop farming somewhere in the world. It would take decades for future crops planted on these lands to absorb the amount of carbon dioxide that is released (due to burning and decomposition of trees, plants and soil) when they are initially cleared for farming.



As a result of direct and indirect changes in land use, use of corn ethanol, soy biodiesel, and other crop-based fuels may result in even greater greenhouse gas emissions than burning gasoline and petroleum diesel, though it is essential to use direct and indirect impacts of petroleum production in any comparison to biofuels production. The scientific analyses for true "apples to apples" comparisons are still being developed, so no firm conclusions can be drawn.

Better environmental results are expected from advanced biofuels, such as those derived from cellulosic sources. Cellulosic fuels, including cellulosic ethanol, can be made from feedstocks such as tree trimmings and switchgrass, which require little or no fertilizer or pesticides. They can be grown on agriculturally marginal lands and thus do not necessarily compete with food production. As a result, they may yield as much as a 90% reduction in carbon dioxide emissions compared with gasoline. But since cellulosic fuel is not yet produced on a commercial scale and the technology is still evolving, there are still uncertainties about environmental impacts—though compared with first generation biofuels, these advanced biofuels offer much promise.

Recommendations of the Task Force:

1. Develop standards for lifecycle evaluation that consider the carbon and environmental impacts of biofuels, including potential impacts on agricultural, forest and other land use in Massachusetts and on a global basis, using definitions like those employed in California and included in the new federal energy law. These evaluations must include both direct and indirect impacts, as well as consideration of impacts on environmental justice. Due to the complexity of lifecycle analysis, to the extent possible Massachusetts should make use of analyses done by other parties, including the California Air Resources Board, U.S. EPA, and the European Union.

2. Lifecycle evaluation methods should put biofuels, petroleum fuels, and other energy sources for vehicles (such as electricity and hydrogen) on a level playing field, assessing secondary and indirect impacts for all.

3. To receive state support for biofuels development and/or use, a particular biofuel must provide a substantial reduction in greenhouse gas emissions relative to petroleum fuels on a lifecycle basis.

4. The state should ensure that developers of refineries meet stringent water discharge limits and select technologies that reduce water needs.

5. Since biofuel made from in-region waste materials, such as waste oils, is likely to have lower greenhouse gas and environmental impacts than biofuel from virgin materials, state agencies should have the latitude to exempt fuel produced from waste materials from a full lifecycle greenhouse gas emissions analysis. However, state agencies should require a review that considers the highest reuse option for the waste feedstock (including recycling) and conduct appropriate environmental reviews of biofuel production processes that seek to minimize potential air and water impacts, as well as chemical and energy use.

6. Support the development and implementation of fuel quality standards (for example, federal ASTM standards) to provide consumer assurance of reliability of advanced biofuels.

Chapter 3 – Biofuel Feedstocks—Energy Crops, Biomass, and Waste Products

In comparison with other states, Massachusetts is not a large agricultural producer, and so has limited potential to benefit economically from first-generation crop-based biofuels such as corn ethanol and soy biodiesel.

The Commonwealth has greater potential to capitalize on second-generation, or advanced, cellulosic feedstocks such as agricultural switchgrass, willow and crambe (an industrial oil crop that grows well in cool climates), agricultural waste products (such as cranberry waste), forest residues and wood from sustainably managed forests, and the organic component of municipal solid waste. Potential benefits include keeping marginal or threatened agricultural lands in production, providing income from open lands not currently in agricultural production, displacing imported fuels, and providing a market for waste oils.

Total in-state feedstocks could replace roughly 6% of petroleum imports, although these same materials are also under consideration for use in electricity generation and thermal applications, where they might displace coal, natural gas, or petroleum fuel, and potentially be used for transportation via plug-in hybrid or electric car technology.

Recommendations of the Task Force:

Note: A variety of tax and other state incentives have the potential to support the development of advanced biofuels feedstocks in the Commonwealth. Recommendations relating to state incentives are discussed in detail in Chapter 6.

1. Conduct additional field trials and commercial demonstration plots on biomass crops in Massachusetts to determine optimal crops, production methods and costs for the state. Trials on marginal agricultural land and other working landscapes are of particular interest. Evaluation of these trials should include environmental impacts (including carbon emissions and soil sequestration) and infrastructure needs for planting, harvesting, and transporting materials.

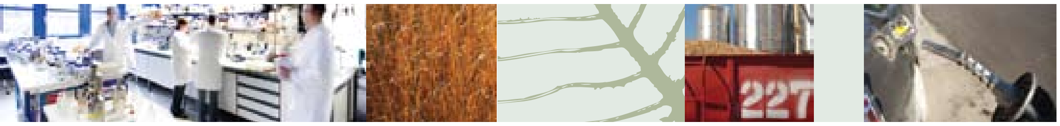
2. Expand a preliminary UMass study on economic potential of energy crops in Massachusetts to include other crops and non-agricultural marginal lands and to improve yield and cost assumptions. Develop a spatial model illustrating potential lands that may be conducive to biomass crops.

3. Support development work (genomic and breeding) on energy crops such as crambe and switchgrass, to improve crop yields and biofuel production.

4. Explore opportunities to promote algae production by the Massachusetts aquaculture industry, and bioengineering research at Massachusetts companies and universities.

5. Conduct an internal review of all state agricultural preservation and assistance programs for the purpose of integrating energy crop production. Explore the benefit of establishing capacity at the state Department of Agricultural Resources and UMass Extension to provide outreach and training to farmers and other landowners interested in establishing early commercial plantations.

6. Complete the current work of the Massachusetts Sustainable Forest Bioenergy Initiative on woody residue and forest biomass feedstock and consider



the potential use of this feedstock for production of cellulosic ethanol.

7. Work with the federal government to support biorefinery technologies and demonstration projects that can be developed on smaller scales to utilize locally available fuel, including waste feedstocks.

8. Investigate the feasibility and design of a statewide program to increase the collection of waste vegetable oil and grease trap waste from restaurants and institutional kitchens and transportation of these wastes to biofuel production facilities. The investigation should consider needs for collecting, transporting and processing these wastes, and the use of technical assistance, incentives and mandates to accomplish these goals.

9. Due to the inherent environmental benefits of reusing waste products over virgin sources of biofuels, give state environmental agencies the authority to reduce or provide exemptions from greenhouse gas emissions lifecycle analysis requirements when applied to biofuels produced from waste feedstocks.

10. Further investigate the applicability of cellulosic waste materials, including the organic portions of municipal solid waste, paper sludge, and construction and demolition debris, for cellulosic ethanol production, while maintaining strict regulatory controls to ensure that no increases in toxics or other pollutants take place.

Chapter 4 - Statutory and Regulatory Mandates, Regulatory Flexibility

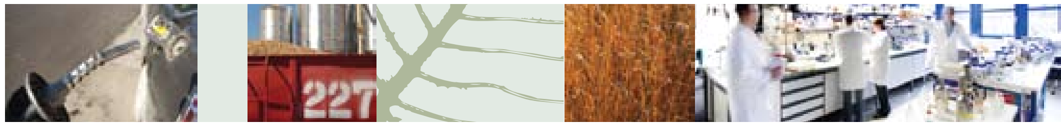
This chapter addresses the principal statutory and regulatory mechanisms available to promote biofuels: a Low Carbon Fuel Standard and content mandates. It also suggests the need for regulatory flexibility to facilitate pilot demonstrations of new technologies.

Content mandates, like those in the federal Energy Independence and Security Act of 2007, require the use of specified amounts of particular biofuels. Some states have enacted content mandates, although in the Northeast they generally apply only to fuel use by state vehicles.

Legislation filed by Governor Patrick, Senate President Murray, and House Speaker DiMasi in November 2007 would exempt cellulosic ethanol from the state gasoline tax and set minimum requirements for the use of biodiesel blends in diesel motor vehicle fuel and Number 2 heating oil sold in the state. The Task Force supports this legislation with amendments that would make it more performance-based and technology-neutral, as well as addressing implementation issues and the need for a transition to a Low Carbon Fuel Standard.

A Low Carbon Fuel Standard (LCFS) is a performance-based, technology-neutral approach that sets limits on greenhouse gas emissions without mandating specific fuel content. It allows the market to drive the development of alternative fuels and technologies at the lowest cost. California is currently developing regulations to implement its LCFS, which would require a reduction of 10% by 2020 in the carbon intensity, on a lifecycle basis, of vehicle fuel sold in California. By not picking winners among technological alternatives to petroleum propulsion, the LCFS allows the best approaches to powering vehicles to win out over time, whether they be biofuels, all-electric vehicles, plug-in hybrids, or hydrogen

Legislation filed by Governor Patrick, Senate President Murray, and House Speaker DiMasi in November 2007 would exempt cellulosic ethanol from the state gasoline tax and set minimum requirements for the use of biodiesel blends in diesel motor vehicle fuel and Number 2 heating oil sold in the state.



fuel cells. Because the market for fuels in the Northeast is regional, rather than state-by-state, and the LCFS is a complex tool, it would be far preferable to implement it on a regional basis.

Recommendations of the Task Force:

1. Prioritize efforts to achieve near-term implementation of a regional, technology-neutral and performance-based Low Carbon Fuel Standard. Position Massachusetts as a leader in this regional development. Given the uncertainty of regional coordination, however, the Commonwealth should also move forward without delay in designing a Massachusetts-specific LCFS that other states and provinces can adopt. The Standard should include lifecycle greenhouse gas reduction standards, as discussed in Chapter 2 of this report, and should reward companies for performance-based results in achieving such reductions.

> A Low Carbon Fuel Standard is a performance-based, technology-neutral way to set limits on greenhouse gas emissions without mandating specific fuel content. By not picking winners among technological alternatives, the LCFS allows the best approaches to powering vehicles to win out over time.

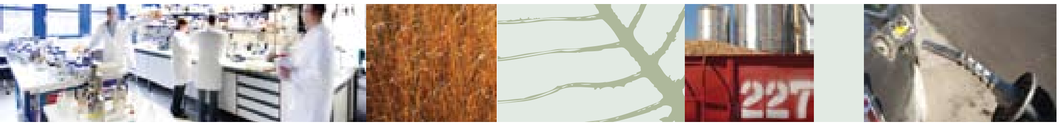
2. Consider incentives to promote the best uses of sustainably harvested biomass, whether as a replacement for transportation fuels or in other energy applications, such as a liquid fuel substituting for heating oil or as a solid fuel used directly for space heating and/or electricity generation. This would move the state farther along the continuum of being technology-neutral, searching for the most cost-effective means of reducing petroleum use and greenhouse gas emissions.

3. While a Massachusetts Low Carbon Fuel Standard is being developed, implement transitional, carefully targeted mandates, such as requirements for minimum percentages of biodiesel in motor and heating fuel. Mandates should require that the fuels yield substantial lifecycle greenhouse gas reductions, including direct and indirect impacts such as those on land use, while not increasing the release of other pollutants; and should be limited, such as by being tied to in-state production of the feedstocks and by phasing out as a Low Carbon Fuel Standard comes into existence. Mandates should be as flexible and technology-neutral as possible. Use of a trading system for meeting the requirements should be considered, although the regulatory complexities this would add must be weighed carefully.

4. The state should ensure that temporary, pilot scale biorefineries are allowed to proceed after review of appropriate environmental safeguards and evidence that the pilot's results will be useful if it succeeds. Analysis of potential contaminants contained in or produced from the processing of waste products such as construction and demolition waste, the organic fraction of municipal solid waste, and biosolids from wastewater treatment plants. MassDEP should review its regulatory authority to determine whether revisions are needed to allow pilot scale waste-to-fuel production. MassDEP should assist in the review of pilot scale projects (whether or not they need a permit) to ensure that, when a proponent seeks approval for a commercial project, those permits can be issued in a timely manner.

5. The state should support the demonstration of operational, maintenance and environmental impacts from the use of waste-based renewable fuels in commercial boilers or turbines. Funding for the purchase of biofuels and to oversee tests done at state facilities may be needed. State environmental agencies should adopt reasonable reporting requirements for those deciding to burn advanced fuels. The continued use of existing permitted fuel, if the advanced biofuel is unavailable, should be allowed.

6. Further research and analysis should be done to evaluate the benefits and costs of policies to support biofuels development



through a regulatory framework, including those in (3) above, on an expedited timeline.

Chapter 5 – Promoting Infrastructure for Delivery and Distribution of Biofuels

For Massachusetts to become a national leader in the development and use of advanced biofuels as a substitute for petroleum, the infrastructure for biofuels delivery and distribution will have to be in place. Consumers will need to be able to use biofuels in their vehicles and homes in order to make them a true alternative to petroleum products.

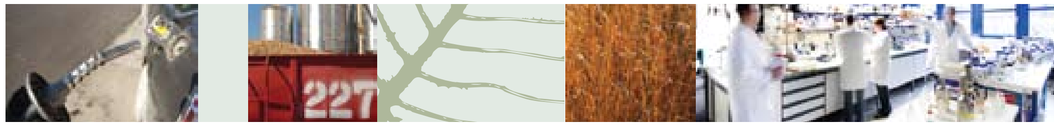
The Commonwealth has no crude oil production, no refining capacity, and no direct service by a major interstate petroleum pipeline. All petroleum products are imported from two main sources: domestic refined products, originating in the Gulf Coast, and imports supplied primarily by Canada, Venezuela and the U.S. Virgin Islands.

While ethanol and biodiesel are both used almost exclusively in blends with petroleum, their supply chain and infrastructure needs differ significantly. For biofuels to transition successfully from the current usage of corn- and soy-based feedstocks in low blends into a significant industry in the region, accommodations will be needed in the mechanisms by which Massachusetts meets its fuel needs in transportation, heating, and other uses—mechanisms that are now geared almost exclusively to the use of petroleum products.

Recommendations of the Task Force:

1. Implement limited-cost investments in infrastructure for ethanol and biodiesel, subject to budget constraints, such as E85 stations along major state highway corridors, and possible assistance for storage and distribution of biodiesel.
2. Study the benefits and costs of measures to increase the share of flex-fuel vehicles in Massachusetts, including mandates and incentives. Such research should take into account both short- and long-term impacts on actual greenhouse gas emissions and other environmental concerns. Explore policies to induce automakers to provide more fuel-efficient flex-fuel vehicle models than are currently available. For its own fleet, the state should purchase flex-fuel vehicles that exceed the average CAFE standard mileage requirements for each vehicle class.
3. Subject to state budget constraints, provide incentives to encourage development of smaller regional biorefineries, especially for cellulosic biofuels, that utilize locally available fuel including waste feedstocks.

4. Support pilot deployment of plug-in hybrid and all-electric vehicles, including flex-fuel plug-in hybrid vehicles, in both light-duty and heavy-duty vehicle classes.
5. Investigate the costs and benefits of incentives for additional heated storage tanks and blending infrastructure at regional terminals.
6. Support rail freight infrastructure for biofuels as part of a broader policy of promoting rail over road freight transportation.



Chapter 6 - Grants, Loans, and Tax Incentives

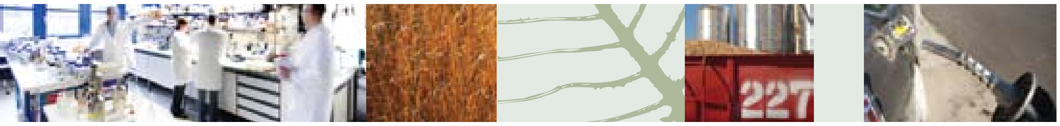
Aggressive expansion of an advanced biofuels industry holds the promise of jobs and economic growth as part of a larger clean energy sector that capitalizes on Massachusetts's advantages in technology, venture capital, sustainable forestry and a highly skilled workforce. In addition, advanced biofuels offer the prospect of environmental benefits in the form of reduced greenhouse gas emissions as they displace the use of imported petroleum in our engines and furnaces. Reducing oil imports is also vital to the energy security of the U.S. as a whole. To realize this promise of global leadership, job creation and retention, economic growth, and environmental benefits, Massachusetts should begin rigorous benefit-cost analysis to identify the financial tools that can develop the sector. Such an effort must necessarily account for revenue impacts and direct and indirect environmental impacts.

As a general matter, state governments have the ability to use their own financial resources to aid particular industries whose growth they see as being in the public interest. Generally, the instruments at their disposal for this purpose include grants, loans, and the state tax code. Massachusetts has used these tools in recent years to provide targeted assistance in a number of areas, including for manufacturers, R&D companies, biotechnology, and the film industry. This chapter discusses the applicability of these options to the emerging biofuels industry, and makes recommendations about how to tailor state financial incentives to maximize the industry's potential in the Bay State.

Most existing federal and state biofuel subsidies, including various tax incentives, are designated for first generation biofuels, mainly corn-based ethanol and soy-based biodiesel. Such policies are common in states with large agricultural sectors, but would have relatively little potential for providing economic benefits in Massachusetts. Advanced, or cellulosic-based, fuels are more promising candidates for support from the Commonwealth, since we have greater ability to supply feedstock for them and produce them.

Recommendations of the Task Force:

1. Exempt cellulosic biofuels from the state's gasoline tax, with a sunset date. An excise tax exemption will encourage fuel distributors to purchase cellulosic ethanol when available, and minimize the risk associated with investment in cellulosic biofuel development.
2. Conduct rigorous benefit-cost analysis of prospective financial support policies for the biofuels industry, comparing benefits (including greenhouse gas reduction, employment gains, energy security, and tax revenues from economic development) with costs (including environmental impacts, state budgetary costs, and consumer/ business expenses).
3. Subject to state budget constraints and lifecycle environmental and greenhouse gas criteria, consider the use of production tax credits and other tax incentives targeted at advanced biofuels production and commercialization in those cases where analysis shows that projected benefits exceed costs. To better assist pre-profit firms, study the implications of making tax credits refundable or transferable.
4. Subject to budget constraints, consider the costs and benefits of implementing state tax credits for the production of in-state biofuel and biomass feedstocks from managed forests and the cultivation of energy crops.



Benefits to be considered should include stimulating investment in forestry and agriculture, improving the market demand and competitiveness of these feedstocks relative to residue sources of woody biomass, and maintaining and improving the Commonwealth's working landscapes. (See discussion in Chapter 3)

5. Subject to budget constraints, authorize state funding for research in partnership with private companies and universities to improve existing technologies for converting wastes, including cranberry and other agricultural residues, to carbon-reducing, environmentally beneficial fuels. Before putting such technologies to work on a wide scale, however, subject the diversion of waste products for biofuels to full environmental and economic analysis. (See discussion in Chapter 3)

6. Subject to state budget constraints and lifecycle environmental and greenhouse gas criteria, create a fund that would provide grants and loans to attract advanced biofuels R&D, demonstration, and production facilities to the Commonwealth in those cases where analysis shows that projected benefits exceed costs.

7. Phase out financial incentives for producers and consumers of biofuels with implementation of a Low Carbon Fuel Standard, since the standard will provide durable incentives to achieve greenhouse gas reductions and displacement of petroleum fuels at the lowest cost to consumers on a performance-based, technology-neutral basis. However, R&D incentives may have a longer-term role in state support for the industry.

8. Include biofuels in priorities for state-level research on renewable energy, presumably associated with a state college or university. This educational institution should take the lead in identifying and pursuing federal funding in collaboration with biofuels companies.

Governor Patrick, Senate President Murray, and Speaker of the House DiMasi announced the creation of an Advanced Biofuels Task Force

Introduction:
Advanced Biofuels Task Force Report

In November 2007, when Governor Patrick, Senate President Murray, and House Speaker DiMasi created the Advanced Biofuels Task Force, the price of oil was about $85 per barrel. During the five months that the Task Force has been doing its work, the price has risen roughly 30%, reaching $110 per barrel. There could be no more compelling evidence that the citizens of Massachusetts need alternatives to imported fossil fuels.

In the same five months, many companies and non-governmental organizations involved in advanced biofuels R&D and production delivered to the Task Force and its members, in public hearings and written testimony, a message that has been clear and consistent: Massachusetts has the technological expertise, the start-up companies, and the venture capital to become the global center for advanced biofuels. With state policies providing support and stimulation to the sector while protecting the environment, Massachusetts could create clean energy jobs, temper price volatility for transportation and heating fuels, reduce emissions of greenhouse gases and other pollutants, and provide new options for Massachusetts consumers now held hostage to imported petroleum.

Biofuels are substitutes for liquid petroleum fuels—including gasoline, diesel, and heating oil—derived from renewable organic matter. The need for substitutes is clear: petroleum products used for transportation and heating oil drain billions of dollars from our economy, and petroleum used in transportation alone is responsible for more than a third of the state's greenhouse gas emissions. Due to limited domestic supplies, reliance on petroleum makes the United States dependent on imports from nations around the world, many of them politically unstable. And we in Massachusetts, having no supplies of our own, pay high prices for imports from abroad and from other parts of the country.

Advanced biofuels, which are defined in federal law as those that yield a net lifecycle reduction of at least 50% in greenhouse gas emissions compared with fossil fuels, offer additional benefits for the environment and for the Massachusetts economy. These low-carbon fuels could play a significant role in addressing climate change. They could also prove to be the basis for a new technology-based industry in Massachusetts. As fuels that for the most part have not yet been brought to market, advanced biofuels are in need of the intellectual capital and R&D strength that Massachusetts has in abundance. Once these products reach commercial viability, in-state production of advanced biofuels derived from feedstock grown in Massachusetts could make a dent in our dependence on imported energy sources, generate jobs at home, and boost the state's growing energy sector. In addition, biofuels have the potential to keep marginal agricultural land in production—a boon for a state that values small-scale agriculture as part of its economic and physical landscape.

Massachusetts has the technological expertise, the start-up companies, and the venture capital to become the global center for advanced biofuels.

Tackling the problems associated with our dependence on and use of petroleum will, of course, require a portfolio of policies such as increasing fuel efficiency in vehicles, encouraging energy conservation and efficiency in buildings, and reducing vehicle miles

> The task force shall develop a strategic framework to accelerate the development and deployment of commercially viable advanced biofuels, and facilitate expansive biofuel research throughout the Commonwealth.
>
> *—Governor Deval L. Patrick, Senate President Therese Murray and Speaker of the House Salvatore F. DiMasi in establishing the Advanced Biofuels Task Force*

traveled. The legislature and executive agencies are working on building this portfolio, but advanced biofuels can provide one more piece of the puzzle.

Thus, the charge of the Task Force was to evaluate the promise of advanced biofuels and to chart a path forward to accelerate the research, development, commercialization and expansion of biofuels in the Commonwealth. The Task Force has concluded that there may indeed be substantial benefits for the state associated with advanced biofuels, but that there are major uncertainties as well.

From an environmental perspective, assessing the impact of biofuels is not a straightforward exercise. Proponents cite the environmental benefits of biofuels: although combustion of biofuels releases carbon dioxide into the atmosphere the same as fossil fuels, the crops, grasses, and trees from which biofuels are derived can be replanted, with the new growth potentially absorbing as much carbon as is released into the atmosphere. Thus, biofuels could potentially be utilized with no net carbon impact. However, biofuels vary in how much they reduce carbon dioxide emissions compared with their fossil fuel equivalent when the analysis takes fully into account the type of feedstocks utilized, the fuels used to convert and transport the feedstocks, and the land on which the feedstocks are grown. For example, ethanol made from corn will have higher carbon dioxide emissions on a lifecycle basis than cellulosic ethanol made from feedstocks like switchgrass or tree trimmings. In addition, if forests are converted to croplands to grow the feedstocks, use of certain biofuels might yield no reduction, or even cause a rise, in greenhouse gas emissions.

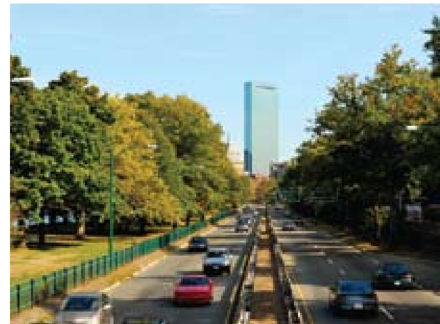
Moreover, the Task Force came to understand that biofuels are but one class of technology that could potentially substitute for petroleum products in powering motor vehicles. As a result, the Task Force was persuaded of the advisability of policies that are performance-based and technology neutral. One such policy that the Task Force recommends is a Low Carbon Fuel Standard (LCFS). A LCFS sets limits on greenhouse gas emissions from vehicle use but does not mandate fuel content or particular technologies for meeting that standard. Such an approach allows the market to drive the development of alternative fuels and technologies at the lowest cost, including not only biofuels but also options such as all-electric vehicles, plug-in hybrids, and hydrogen fuel cells. California is currently drafting regulations to implement its LCFS, which would require a reduction of 10% by 2020 in the carbon intensity, on a lifecycle basis, of vehicle fuel sold in the state.

Like the climate benefits, the economic picture for advanced biofuels is characterized by both promise and uncertainty. In terms of promise, the Task Force estimates the potential production of cellulosic ethanol from Massachusetts feedstocks at about 160 million gallons per year, or 6% of the gasoline consumed in the state in 2006. It finds that Massachusetts is ideally positioned to capture the benefits of companies that develop cellulosic technology. In total, a mature advanced biofuels industry—including technology development, in-state feedstock cultivation, and processing into fuel—could contribute $280 million to $1 billion per year to the Massachusetts economy by 2025, while generating 1,000 to 4,000 permanent jobs and 150 to 760 temporary construction jobs. Including indirect "multiplier" effects, the annual permanent gains could rise as high as $550 million to $2 billion and 2,500 to 9,800 jobs.

However, the Task Force notes substantial uncertainties associated with these estimates. The calculation of benefits assumes the resolution of infrastructure barriers, technological challenges, and the very economic viability of advanced biofuels themselves.

In light of these uncertainties, the recommendations of the Task Force reflect an intention to proceed strategically and cautiously with biofuels development—but to proceed nonetheless. While the remainder of the report presents a broad array of findings and recommendations, the major Task Force recommendations include the following:

- Prioritize efforts to achieve near-term implementation of a regional, technology-neutral and performance-based Low Carbon Fuel Standard (LCFS), with Massachusetts leading the way.
- While a LCFS is being developed, implement targeted transitional mandates, such as requirements for minimum percentages of biofuels in blends of transportation diesel and heating oil. Mandates should require that the biofuels yield substantial lifecycle greenhouse gas reductions, including direct and indirect impacts such as those on land use. Also as an interim measure, exempt cellulosic biofuels from the state gasoline tax with a sunset date. The core ideas of both content mandates and exemption of cellulosic biofuels from the gasoline tax are included in the biofuels bill filed by Governor Patrick, Senate President Murray, and House Speaker DiMasi.
- Support pilot deployment in the state fleet of plug-in hybrid and all-electric vehicle technology in light-duty and heavy-duty vehicles, as well as fuel-efficient flex-fuel vehicles in order to explore the potential of electric propulsion along with biofuels in meeting a LCFS.



- Develop infrastructure necessary for consumer use of biofuels—implement limited-cost investments in equipment for ethanol and biodiesel distribution, such as E85 stations along major state highway corridors, subject to budget constraints.
- Develop standards for full lifecycle evaluation of biofuels that consider their carbon and other environmental impacts, including potential direct and indirect land use impacts. Due to the complexities involved, rely to the extent possible on analyses performed by authorities in other jurisdictions.
- Parallel to progress on biofuels, continue to explore policy options for increasing vehicle efficiency and reducing vehicle miles traveled.

Chapter 1:
The Economic Potential of an Advanced Biofuels Sector in Massachusetts

As a new and growing industry, biofuels could add to the Commonwealth's economic engine, starting and attracting companies, creating and retaining jobs, and growing the Massachusetts clean energy sector. Furthermore, biofuels offer alternatives to our current reliance on petroleum-based fuel sources—a dependency that sends economic benefits out of state, to foreign countries or other parts of the U.S.

This chapter is designed to provide a preliminary assessment of the potential economic benefits to Massachusetts of an advanced biofuels sector.* This discussion focuses solely on advanced biofuels—defined as renewable fuel that reduces net lifecycle greenhouse gas emissions by at least 50%. First-generation biofuels, such as corn-based ethanol and biodiesel produced from oils and fats, have a role to play in the short run. But it is advanced biofuels—which have not yet reached commercial viability—that hold the most promise for clean, reliable, renewable energy for the future, and for economic development in the Commonwealth.

Economic benefits associated with biofuels are expected to come from three main sources: technology development, use of biomass feedstock from in-state sources, and construction and operation of processing facilities. Technology development would leverage Massachusetts's strengths in technical know-how, entrepreneurship, and venture capital to create new companies and bring new products to national and international markets. Use of local cellulosic materials would have particular value for the local economy, retaining jobs in forestry and agricultural industries that might otherwise be lost. Production of advanced biofuels using local cellulosic feedstock also has high economic value because Massachusetts has no fossil fuel resources of its own. Consequently, residents and businesses in the Commonwealth spend billions of dollars a year to buy petroleum fuels from other states and countries—a large drain on our economy. In-state feedstocks could replace on the order of 6% of our petroleum use, and substantially more could come from other Northeastern states (see Chapter 3)—a significant amount, but still a small fraction of total consumption.

To the degree that biofuels are used by consumers in Massachusetts, but the feedstocks are grown and processed into fuels in other states, our spending on fuel imported from outside the state would not be reduced. There are, however, economic and political gains to the U.S. as a whole from reducing petroleum imports from other countries.

Economic gains to Massachusetts come first from the "direct" economic activity in companies engaged in research and development, in providing biomass feedstocks,

* The analysis in this chapter was conducted by Navigant Consulting, Inc. and Task Force staff, looking at feedstock potential within the state and at potential development of the R&D sector. Final calculations of direct impacts were made by Task Force staff, and converted to total impacts by applying estimates of economic multipliers for Massachusetts. The multipliers are based on a high-level review of multipliers for economic sectors relevant to biofuels, generated by the IMPLAN model and provided by Economic Development Research Group. See Appendix A for a more complete treatment of methodologies used in Chapter 1.

in operating processing facilities, and in constructing such facilities. There are also secondary "multiplier" (also known as indirect and induced) gains as biofuel companies buy products and services from other firms in Massachusetts, and as employees spend their incomes within the state.

Cellulosic fuels are not expected to reach competitive levels in the marketplace for at least five years, and after that their production will develop over time. The analysis below assumes that by 2025 the industry will have grown to the point where Massachusetts's in-state resources of cellulosic feedstock are used on a large scale for processing into biofuels at in-state facilities.

We estimate permanent annual economic potential—from technology development, feedstock provision, and facility operation —at 1,000 to 4,000 jobs, and $280 million to $1 billion in annual gross state product by 2025. With multiplier effects for indirect impacts added in (as spending re-circulates throughout the state's economy), the potential gains rise to 2,500 to 9,800 jobs and $550 million to $2 billion in economic activity.

Table 1.1: Summary of Economic Opportunities from Advanced Biofuels (annual as of 2025 except for construction)

	Low	Middle	High
Direct impacts			
State product ($ millions)			
Permanent	$280	$640	$1,000
Construction (temporary)	$20	$70	$110
Employment (number of jobs)			
Permanent	1,000	2,500	4,000
Temporary construction	150	460	760
Total impacts including multiplier			
State product ($ millions)			
Permanent	$550	$1,270	$1,990
Construction (temporary)	$50	$160	$260
Employment (number of jobs)			
Permanent	2,500	6,200	9,800
Construction (temporary)	350	1,050	1,750

This overall potential can be broken down into its constituent parts. One major part, advanced biofuels technology development, can serve national and global markets. We estimate that technology development could yield 630 to 2,000 direct jobs, and $125 million to $400 million in gross state product. Including indirect and induced impacts, the total gains would be 1,600 to 5,300 jobs and $270 million to $850 million.

The second major economic potential is from biofuel production in Massachusetts, but it is unclear to what extent in-state biomass will be used for biofuels consumed here and how much processing will be done here. Assuming varying levels of in-state industry development, we estimate direct, permanent gains to the state's economy of 380 to 2,000 jobs and $150 million to $600 million in gross state product. Including multiplier effects, the total gains would be 860 to 4,600 jobs and $280 million to $1.14 billion.

In addition, there will be jobs and economic gains from construction during those years when processing and other facilities are being built. If these were spread evenly over a 15-year period, for example from 2010 through 2025, the average direct benefits would be 150 to 760 jobs and $20 million to $110 million. Including indirect/induced impacts, the state would realize 350 to 1,750 jobs and $50 million to $260 million.

Additional economic benefits may include cost savings to consumers (if biofuels are less expensive than fossil fuels), increased state tax revenues, lower health care costs from cleaner air, and reduced energy price volatility. These have not been quantified in this preliminary assessment, but should be part of a more comprehensive analysis of economic potential.

The Advanced Biofuels Sector: Current Status and Future Potential

The recently published "Massachusetts Clean Energy Industry Census"[1] reports that "Clean Energy" is the fastest growing sector of the state's economy, already supporting 14,400 jobs and 556 companies across the Commonwealth. Renewable energy is a key component of this cluster of economic activity, with the report highlighting that "renewable energy companies are the youngest and fastest growing firms."

Overall, the size of the state's existing biofuels sector is small. There is some "downstream" activity as petroleum wholesalers and retailers blend conventional biofuels into refined petroleum products (often to comply with federal and state regulations). On the other hand, there are minimal "upstream" activities, such as biomass cultivation and collection. In terms of technology development, a surge of interest in the sector has occurred recently, with five to eight early-stage technology companies emerging in Massachusetts in the past few years alone.[2] This suggests that the state is well-positioned to capture future growth in this area.

As discussed in the appendix to this chapter, for purposes of the economic impact analysis it is necessary to distinguish between the operational deployment and technology development value chains. It should be noted that this distinction reflects, to a certain degree, a geographic divide—with the more rural areas of western Massachusetts expected to accrue a larger share of economic benefits on the operational side of the advanced biofuels sector, and the state's eastern urban centers reaping more of the technology development benefits.

Operational Deployment

Massachusetts has only modest agriculture and forestry sectors and is not considered a major area of biomass feedstock supply. Other New England states—primarily Maine with its large forest products sector and forest biomass resource base—have more substantial potential. Nevertheless, given the promise of biofuel technologies under development that will be able to convert a broad range of feedstocks (including agricultural and forestry residues, industrial and urban wastes), the potential displacement of petroleum imports with biofuels produced from local feedstocks can result in important economic benefits for Massachusetts.

First-generation biofuels, such as corn-based ethanol and biodiesel produced from oils and fats, have a role to play in the short run. But it is advanced biofuels—which have not yet reached commercial viability—that hold the most promise for clean, reliable, renewable energy for the future, and for economic development in the Commonwealth.

To characterize the range of potential feedstock supplies from within the state for advanced biofuels production by the year 2025,[3] three distinct scenarios (Low, Medium and High) were developed based on a review of publicly available literature.[4] It is important to emphasize that the potential in-state production of conventional biofuels was not considered (although this is discussed in Chapter 3).[5] The next 20 years will likely see the emergence of a number of conventional biofuel operations, predicated mostly on feedstock imported from out-of-state. These operations will generate some economic benefits despite the more limited value created for the local economy when feedstock is imported.

Table 1.2: Feedstock Availability and Biofuels Production Potential in Massachusetts									
2025 Scenario	Available Biomass Feedstock (1,000s Dry Tons / Yr)							Biofuels (GGE[1])	
	Forest Residues	Mill Residues	Dedicated Energy Crops	Urban Wood Wastes[3]	Organics from Municipal Solid Waste[4]		Total	Average Yields (GGE / ton)	Production (MGPY[2])
					Disposed[5]	Recycled[6]			
Low	100	100	150	500	700	100	**1,650**	60	**100**
Medium	200	150	250	800	900	200	**2,500**	80	**200**
High	350	200	600	1,000	1,200	400	**3,750**	100	**380**

1: Gallons of Gasoline Equivalent

2: Million Gallons of Gasoline Equivalent Per Year

3: Includes yard wastes (recycled and disposed) + biomass fraction of C&D waste (recycled and disposed)

4: Organics Fraction of MSW: includes paper, food waste, food scraps, other. Excludes all yard waste & C&D

5: Landfilled & Incinerated

6: Recycled, Composted and otherwise diverted - Lower figures reflect challenges of diverting from other uses

> We should be harnessing our research abilities and entrepreneurial spirit to develop and commercialize the next wave of renewable biofuels—sources of energy that (1) create local jobs; (2) increase energy independence; (3) promote fuel diversity; and (4) significantly reduce greenhouse gas emissions.
>
> *—Environment Northeast, testimony to the Massachusetts Advanced Biofuels Task Force, January 17, 2008*

Table 1.2 summarizes the results of this analysis, as well as the estimated breakdown between the main feedstock categories for each scenario.

Assuming the medium scenario in Table 1.1, advanced biofuels production in 2025 would total 200 million gallons per year, displacing over 6% of 2006 gasoline consumption in Massachusetts. The size of individual facilities will be the result of trade-offs between economies of scale in construction and operations and diseconomies of scale in feedstock procurement. Based on current forecasts, advanced biofuels plant sizes will range between 10 million and 60 million gallons of gasoline equivalent per year.

Technology Development

Technological innovation is an area of strength for the Massachusetts economy due to the presence of superior academic institutions and technology clusters in the biotech and defense sectors. As a consequence, the state is well-suited to attract economic activities in this area, as evidenced by the increase of early stage companies that have surfaced over the past few years and the academic partnerships established to attract private and public R&D funds for advanced biofuels development.

Attempting to estimate the size of an advanced biofuels R&D sector and its impacts on the Massachusetts economy in 20 years is difficult given the uncertainties facing this emerging industry. Unlike feedstocks, intellectual property—the product of technological innovation—is readily transferable and can create significant value for the state. Technology development activities are, therefore, not constrained by local circumstances, but can serve national and global markets.

The Advanced Biofuels Sector: Economic Impacts

Operational Deployment

Price projections from the U.S. Department of Energy's Energy Information Administration were used to estimate the total economic value generated by advanced biofuels operations in 2025 for the three scenarios described in Table 1.1.[6] Other assumptions are outlined in the appendix.

Tables 1.3a and 1.3b summarize the results of the analysis: the operational deployment of advanced biofuels has the potential to generate an incremental direct economic impact on the Massachusetts economy in the year 2025 estimated at approximately $150 million to $600 million annually (for the Low and High case scenarios, respectively). A high-level review of economic development multipliers for the Massachusetts economy suggests that

Table 1.3a: Annual Direct Economic Output Gains in 2025 – $ millions				
	Low	Medium	High	Comment
Construction - Average over 15 Years	$23	$68	$114	Temporary
Operations	$150	$375	$600	Permanent
Technology Development	$125	$263	$400	Permanent
Total $ millions	**$298**	**$706**	**$1,114**	
***of which* Permanent Only ($ millions)**	**$275**	**$638**	**$1,000**	

Table 1.3b: Annual Total Economic Output Gains Including Multiplier Effect in 2025 – $ millions				
	Low	Medium	High	Comment
Construction - Average over 15 Years	$52	$157	$262	Temporary
Operations	$285	$713	$1,140	Permanent
Technology Development	$266	$558	$850	Permanent
Total ($ millions)	**$602**	**$1,427**	**$2,252**	
***of which* Permanent Only ($ millions)**	**$551**	**$1,270**	**$1,990**	

for every $1 million of direct economic output that is created, $0.9 million of indirect and induced output is also generated.[7] Therefore, if $600 million a year of direct output is created, the true impact on economic activity is approximately $1.14 billion annually. The results also highlight that the lion's share of this economic benefit occurs in the following segments of the value chain:

- "Feedstock Production and Collection", i.e. the agricultural, forest products and waste management sector of the local economy; and
- "Biofuels Production", i.e. the industrial processing sector.

In addition to direct output, the analysis examined economic impacts from operational deployment in terms of direct jobs created. Key assumptions are outlined in the appendix. Tables 1.4a and 1.4b summarize the results of the analysis: the operational deployment of advanced biofuels is estimated to generate between 375 and 2,000 permanent direct jobs and between 150 and 760 temporary construction jobs, with salaries ranging from $30,000 to $75,000. The multiplier for indirect and induced employment effects is

Table 1.4a: Direct Jobs Created – Annual in 2025 (except construction)				
	Low	Medium	High	Comment
Construction - Job Years Total	2,250	6,825	11,400	Temporary
Construction - Average over 15 Years	150	455	760	Temporary
Operations	375	1,188	2,000	Permanent
Technology Development	625	1,313	2,000	Permanent
Total jobs	**1,150**	**2,955**	**4,760**	
***of which* Permanent jobs only**	**1,000**	**2,500**	**4,000**	

Table 1.4b: Total Jobs Created Including Multiplier – Annual in 2025 (except construction)				
	Low	Medium	High	Comment
Construction - Average over 15 Years	345	1,047	1,748	Temporary
Operations	863	2,731	4,600	Permanent
Technology Development	1,641	3,445	5,250	Permanent
Total jobs including temporary	**2,848**	**7,223**	**11,598**	
***of which* Permanent jobs only**	**2,503**	**6,177**	**9,850**	

1.3—meaning that for every direct job created, 1.3 additional indirect and induced jobs are expected to result.

Technology Development

The economic impact of early stage technology development is generally measured in terms of R&D investment capital provided through public funding and private investors. Over the long-term, technologies are expected to be commercialized, generating a return on those investments. While different firms use different business models to reap the benefit of technology innovation, the pure value of technology development can be estimated by the sale of intellectual property through royalty payments. For this analysis, the economic impacts of technology development are measured in terms of the stream of potential royalty revenues generated from commercialized advanced biofuels technologies (i.e. the value of goods and services). The analysis assumes that by the end of this period (2025), the biofuels industry will have matured substantially from its current state.

> UMass has formed an interdisciplinary team of forward-looking researchers whose work is aimed at the development of cost-effective technologies for producing ethanol, alternative fuels, and other value-added materials from biomass.... This work has already led to the creation of one commercial spin-off from UMass–Amherst: SunEthanol, a biofuels company that is developing a cellulosic ethanol production technology.
>
> *—A Report of the UMass Clean Energy Working Group, February 2008*

Based on assumptions detailed in the appendix, the incremental direct output generated in the local economy is estimated in the range of approximately $125 million to $400 million per year. This value could increase significantly if Massachusetts-based companies participate not only by selling technology but also, for example, by providing engineering and operation and maintenance services to plant owners, or owning and operating facilities globally. In addition, the technology platforms now under development for biofuels will provide valuable breakthroughs for large-scale production of bio-based chemicals and products to replace those derived from fossil fuels.[8] The value of the intellectual property created for these applications will generate additional benefits for the state's economy that have not been estimated here.

Finally, potential direct job creation from advanced biofuels technology development is estimated at 625 to 2,000 jobs per year. Moreover, job quality as measured in terms of average expected salary is higher in this area of activity than for jobs related to operational deployment.[9]

This economic impact analysis does not discuss or consider the large risks and challenges facing the advanced biofuels industry. Rather, it assumes that the core risks and challenges are successfully addressed, allowing advanced biofuels to become a viable and integral part of the energy sector. Substantial technological performance improvements and scale-up, as well as infrastructure barriers, lie ahead. The economic viability of advanced biofuels still needs to be proven and the true extent of the environmental benefits and downsides require additional analysis, as discussed in subsequent chapters of this report.

Methodological Appendix

See Appendix A to this report for further information on the methodology used in this chapter.

Chapter 1 Endnotes

1. Massachusetts Clean Energy Industry Census, Mass. Technology Collaborative, August 2007, http://www.mtpc.org/Clean-Energy-Census-Report-2007.pdf

2. Companies include: Verenium, Mascoma, SunEthanol, Agrivida, BioEnergy International, GreenFuel Technologies. All have received substantial venture funding.

3. The choice of the year 2025 is arbitrary, but reflects the need to look at a period in time that is far enough in the future for the industry to have matured substantially from its current stage in terms of technology, markets, and infrastructure, in order to achieve its economic development potential.

4. List of literature reviewed:

    - "A Geographic Perspective on the Current Biomass Resource Availability in the United States", A. Milbrandt. NREL, December 2005.
    - "Estimated Annual Cumulative Biomass Resources Available by State and Price", ORNL. March 1999.
    - "The Woody Biomass Supply in Massachusetts: A Literature Based Estimate", Northeast Regional Biomass program (NRBP). May 2002.
    - "U.S. Biofuels Production Potential" based on spreadsheet developed by the National Biomass Partnership. August 2007.
    - "25% Renewable Energy for the United States by 2025: Agricultural and Economic Impacts", 25x25 Coalition. November 2006.
    - "Waste Reduction Program Assessment and Analysis for Massachusetts", February 2003, MA DEP http://www.mass.gov/dep/recycle/priorities/tellrep.pdf
    - "2006 Solid Waste Data Update on the Beyond 2000 Solid Waste Master Plan", February 2008, MA DEP http://www.mass.gov/dep/recycle/priorities/06swdata.doc
    - "Identification, Characterization, and Mapping of Food Waste and Food Waste Generators in Massachusetts. Final Report" September 19, 2002. Prepared for MA DEP. Bureau of Waste prevention.

5. The production of biodiesel or heating oil substitutes from used vegetable oil and animal fat (commercially known as Yellow Grease, YG, and Trap or Brown Grease) is not considered in this economic impact analysis for two reasons: 1) The feedstock potential in the state for this application is limited; and 2) Used vegetable oils recycled mainly from commercial food establishments in the state are already upgraded to a valuable commodity such as YG by the local rendering industry (#2 YG is traded at about 50% of the value of virgin vegetable oil, currently at about 20 cents/pound); economic value is already created in this operation and the economic impact to the state's economy of further upgrading YG to biodiesel (or using it directly as fuel) is limited. This choice, however, is not meant to diminish the societal value of this application or the potential benefit to certain sectors of the local economy from further enhancing the value of the resource. Similar considerations may apply for the recycled fraction of solid biomass waste that we considered in Table 1.2.

6. High Price Case Projections AEO 2007. http://www.eia.doe.gov/oiaf/archive/aeo07/pdf/aeohptab_12.pdf. The analysis uses the projected price for gasoline and discounted for taxes,

retail distribution costs and margins to obtain a wholesale price applicable to advanced biofuels—value used is $2.70/GGE.

7. Using IMPLAN and considering the following economic sectors: grain farming, logging, forest products and timber, corn wet milling, agriculture and forestry support activities, sawmills, pulp mills, paper and paperboard mills, paperboard container manufacturing, water transportation, truck transportation.

8. Demand for degradable plastics (just one of the potential commercial applications of the technology platforms) is expected to rise from 100 million lbs. in 2000 to 500 million lbs. in 2010.

9. Anecdotally, the average salary for jobs in biotechnology in Massachusetts (a similar job profile to jobs expected to be created in advanced biofuels technology) is about $100,000 per year.

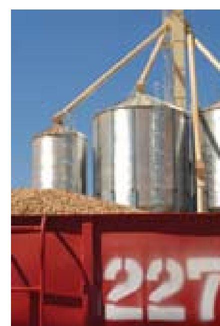
Chapter 2:
The Energy and Environmental Lifecycle of First Generation and Advanced Biofuels

Energy production and use is central to our economy and way of life, but can also cause environmental harm in the form of air and water pollution, land degradation, and damage to wildlife and biodiversity. Burning of fossil fuels (coal, oil, natural gas) for electricity generation, space heating, industrial processes, and transportation causes air emissions that harm human health in the U.S. (the effect of so-called “criteria” air pollutants such as sulfur dioxide, nitrogen oxides, particulates, and carbon monoxide). Fossil fuel combustion is also by far the dominant source of emissions associated with global climate change, with carbon dioxide the primary greenhouse gas.

Biofuels can replace a portion of the petroleum and other fossil fuels that we use, and have the potential to mitigate some of the pollution caused by fossil fuel combustion. It is because of this that biofuels have received so much attention as part of a portfolio of strategies to reduce fossil fuel-based emissions. However, the effect of such replacement on emissions is far from a settled question.

Evidence to date indicates that, depending on the particular fuel and conversion process, the use of biofuels can increase, decrease, or hold roughly constant various air pollutants. In regard to greenhouse gas emissions, the present state of research indicates that, depending on what feedstocks are used, how they are processed, and how their cultivation affects land use worldwide, increased use of biofuels could either reduce or raise emissions. Furthermore, this research is by no means complete. For instance, there has been little analysis of the positive greenhouse gas impact that could be achieved by protecting land and changing its use from potential sprawl development into production of woody biomass feedstock—an impact of particular interest in a region like the Northeast, which could provide significant cellulosic feedstock from the careful harvesting of forested land.

Unlike other renewable energy sources like wind and solar, the greenhouse gas impact of biofuels is complicated. When a biofuel such as ethanol or biodiesel is burned, carbon dioxide is released, just as it is with fossil fuels. Unlike fossil fuels, however, the crops, grasses, or trees from which biofuels are derived can be replanted and grown again. When plants grow, they absorb carbon dioxide, thus potentially canceling out the emissions that occur when they are burned. This potential is dependent, however, on whether harvesting and replanting are done sustainably, with crops consumed for energy continuously being replaced with equivalent new crops.



Both fossil fuels and biofuels require energy and create pollution not only when burned, but throughout their lifecycles. Fossil fuels must be extracted from the ground, transported, processed or refined, and then burned to release their energy. For biofuels, energy crops must be grown, harvested, transported, and processed into fuels before being burned for energy. Plant crops are a particularly “dispersed” source of energy, requiring large expanses of land to produce the volumes of feedstock needed. Some feedstocks, particularly corn and certain other food crops, also require carbon- and chemical-intensive inputs, such as fertilizers and pesticides, to grow well. Converting feedstocks into ethanol and biodiesel is also energy intensive.

In addition, demand for fuel crops puts pressure on the world's supply of food, raising food prices and shifting previously uncultivated land into food production, with consequences for greenhouse gases. For example, if forests are cut down to plant crops, large volumes of carbon that were contained ("sequestered") in the soil may be released. This happens in several ways. First, trees and plants may be burned to clear the land, causing large short-term emissions of carbon dioxide. Second, dead trees and plants decompose, gradually releasing carbon dioxide and in some cases methane, another greenhouse gas. Third, there is actually more carbon in the soil itself than in all the trees, plants, and atmosphere above the ground. When soil is disturbed to grow crops, oxygen becomes available to it, stimulating biological activity that once again converts carbon into carbon dioxide.[1]

Besides greenhouse gas emissions, the lifecycles of both petroleum and biofuels contribute to other air pollutants, as well as to water pollution from exploration, drilling, transportation, growing, processing, and use. Of particular concern with biofuels is runoff of fertilizer and pesticides into rivers and other water bodies, and subsequent pollution of downstream resources. Corn production in the Midwest, for instance, deposits fertilizer into the Mississippi River and is blamed for creating a large and growing "dead zone" in the Gulf of Mexico. Such problems could escalate as production volumes increase, and as crop prices rise due to higher demand, leading to more intensive use of fertilizer to increase yields per acre. Apart from pollution, increased water use may also be a problem for both corn-based and cellulosic ethanol production as water supplies become tighter around the country.

At the same time, greenhouse gas emissions, water use, and pollution related to petroleum are likely to increase as oil is extracted from more difficult sources, such as Canadian tar sands—as is projected to happen as worldwide demand for oil continues to increase and ever-higher prices make such oil sources economic to develop. These impacts are relevant in comparing the environmental lifecycles of biofuels and petroleum.

Analyzing Greenhouse Gases of Biofuels over their Lifecycles

Attempts to measure the full lifecycle greenhouse gas impacts from biofuels in comparison with petroleum have given rise to a number of analytical models. Until recently, however, these models did not take into account the indirect impacts of changes in land use caused by increased biofuels production. Two ways this can occur are (1) higher demand and prices for corn (whose production is energy-intensive) cause land to be shifted from other, less energy-consuming crops, and (2) use of crops for fuel in one location causes land to be converted from non-crop to crop use elsewhere.

Earlier analysis indicated that corn-based ethanol yielded moderate but significant reductions—on the order of 20%—in greenhouse gas emissions relative to petroleum. Soybean-based biodiesel was estimated to yield greater savings, close to 70%. The inclusion of indirect land use impacts changes these equations dramatically, however, with recent research estimating that use of corn ethanol and crop-based biodiesel could yield large increases in net greenhouse gas emissions compared with petroleum.

Impacts Without Considering Indirect Land Use Change

Without considering indirect land use impacts, researchers agree that the currently dominant biofuel in the U.S., corn-based ethanol, yields a relatively small reduction in greenhouse gas emissions compared with petroleum, due to the high inputs of energy needed to grow, process, and transport it. The U.S. EPA, utilizing the GREET model developed by Argonne National Laboratory, estimates that corn ethanol yields a 22% reduction in greenhouse gas emissions over its lifecycle.[2]

Even that impact depends on what fuel source is used to process the corn into ethanol—natural gas, coal, or waste byproducts from the corn itself—and on other aspects of production. The Natural Resources Defense Council examined ethanol produced under a variety of conditions and found that, with coal used as the fuel source for processing, total emissions were slightly higher than for gasoline. However, with several improvements—including use of waste biomass for processing, locating the plant near a livestock farm so that the byproducts can be sold in a wet form and employment of low-till agriculture—the net benefits from corn ethanol relative to petroleum could be increased to well above EPA's 22% estimate.[3]

To be eligible for the biofuel volume mandates of the recently passed federal law, the Energy Independence and Security Act of 2007, corn-based ethanol from new plants must yield a 20% reduction in greenhouse gas emissions. The law requires that both direct and indirect impacts, including indirect land use, be included in the analysis. However, there are provisions in the law that leave great uncertainty concerning the actual reductions that will occur. First, the U.S. Environmental Protection Agency (EPA) administrator has discretion to reduce the requirement to as little as 10%. Second, existing plants do not have to meet the 20% requirement, and the law does not prevent large expansions in the output of these plants.[4]

In comparison with corn ethanol, soybeans require far less fertilizer, pesticides, and water to be grown and turned into biodiesel. Per unit of energy gained, biodiesel requires only 1% of the nitrogen, 8.3% of the phosphorous, and 12% of the pesticides by weight used for the growth of corn-based ethanol.[5] As a result, biodiesel has far less fossil-fuel energy embodied in its lifecycle. Without consideration of indirect impacts from land use and other factors, the EPA estimated a 68% reduction in greenhouse gas emissions relative to petroleum diesel.

The Energy Independence and Security Act of 2007 includes provisions stating that fuels eligible for its mandates can only be derived from feedstocks grown on land that was cleared for crops or for tree plantations prior to enactment of the law. This definition of "renewable biomass" would appear to prevent direct conversion of forests to fuel production from being eligible.[6] The provisions would not address the "indirect" impacts discussed below.

The 2007 Act contains separate definitions for "advanced" and "cellulosic" biofuels. "Advanced" fuels are defined as those yielding lifetime greenhouse gas reductions of 50% or more. Since estimates of these reductions are in early stages of development, we do not yet know which biofuels will qualify. In particular, soy-based biodiesel would meet this threshold if indirect impacts on land use changes are excluded or turn out to be small, but may not qualify as "advanced" if research determines that substantial indirect land use impacts should be included.

Biofuels derived from cellulosic materials, such as cellulosic ethanol, promise much greater reductions in greenhouse gas emissions than do food-crop biofuels such as corn ethanol—and with fewer environmental costs. To qualify as cellulosic biofuel under the 2007 federal energy law, fuels must yield 60% or greater lifetime greenhouse gas reductions, including direct and indirect impacts. Cellulosic feedstocks include switchgrass, woody plants, agricultural waste

When plants grow, they absorb carbon dioxide, thus potentially canceling out the emissions that occur when they are burned. This potential is dependent, however, on whether harvesting and replanting are done sustainably, with crops consumed for energy continuously replaced with equivalent new crops.

New crops and conversion technologies are developing rapidly that will make it easier to produce lots of biofuels with a smaller environmental footprint, but the technologies are not a guarantee of good environmental performance. We need strong environmental safeguards and performance standards guiding the market so that innovation and competition will drive biofuels to provide the greatest benefits.

—Nathanael Greene, Natural Resources Defense Council

(for example, from cranberry production) and various prairie grasses, all of which require far less energy-intensive inputs than do food crops. One analysis that did not take into account indirect land use changes estimated that combustion of cellulosic ethanol only results in 1.9 pounds of net carbon dioxide emissions per gallon, a reduction of over 90% compared with conventional gasoline.[7] It should be noted that these numbers are subject to uncertainty, since cellulosic ethanol has not yet reached commercial production and the technology behind it is rapidly evolving.

A key advantage of cellulosic feedstocks, and one that is agreed upon by a wide variety of studies, is their ability to thrive on agriculturally marginal lands that don't compete with food production for land use, and have the potential to deliver significant greenhouse gas reductions. However, it is possible that land currently producing food crops could be converted to energy crops, in which case the issue of global land use changes, and the associated dangers of large increases in greenhouse gas emissions and disruption of food supplies, would remain serious problems.

Indirect Impacts from Land Use Changes

In addition to greenhouse gases associated with crop growth and processing into biofuel, environmental impacts occur when areas such as forests or grasslands are converted into cropland. Such conversion releases large amounts of carbon from the soil, while the trees and grasses that had absorbed carbon dioxide are removed (although the new fuel crops will absorb some of this gas as well). Depending on the prior use of the land, the carbon releases can be very large relative to reductions in use of fossil fuels, resulting in what some researchers have termed a "carbon debt."

Land use impacts can be direct or indirect. Direct impacts take place when land is converted from non-crop use in order to produce biofuel feedstock. Two causes of indirect impacts are when existing cropland is converted from one crop to another, or when cropland is used for fuel instead of for food, creating the need to till other land for food crops. The effect of these shifts in use may not be apparent on a local, state, or even national level, but on a global scale could reduce food supplies and raise prices as land is converted from forest or grassland to crops—or food crop to fuel crop—in places around the world.

The first cause of conversion may result from increases in the price of one crop, causing farmers to shift toward that crop. For example, as ethanol demand has risen so have corn prices, causing a recent substantial rise in the U.S. acreage planted. At the same time, U.S. soybean acreage has fallen, possibly due to conversion to corn. Since corn requires far more energy in its lifecycle, this shift results in higher greenhouse gas emissions.

In regard to conversion from food to fuel crops, a recent study by the European Organization for Economic Cooperation and Development finds that biofuels have probably had relatively small impacts on world food markets to date, but could have much larger impacts in the future. This study estimates that production of ethanol and biodiesel could increase 160% by 2016 to 125 billion liters. That would require "about one-third of cereal land in the United States and in Canada and about half of the cereal, oil seeds, and sugar beets land in the European Union," causing "a major impact on agriculture commodities prices."[8]

Some of the earliest work on greenhouse gas impacts from land use conversion was done by Dr. Mark A. Delucchi of the Institute of Transportation Studies at the University of California–Davis. Delucchi estimated that the conversion of forest soils to croplands leads to a decrease of carbon content in the soil by 40% to 50% over the course of a few years. Conversion of range to cropland can reduce the carbon content of soil by 20% to 40% over a similar period. Conversely, cellulosic energy crops such as switchgrass or short rotation poplar plantations increase soil carbon content if they replace traditional row crops such as corn, but reduce carbon content in the soil if they replace forests.[9]

European consumption currently dominates world demand for biodiesel, which represented about 7% of world vegetable oil production in 2007.[10] The vast majority of this comes from rapeseed oil grown in Europe, due to high subsidies for domestic production. But this demand has resulted in a shortage of domestic food oil supplies, leading Europe to double its imports of palm oil from 2000 to 2006.[11] Meanwhile, the cultivation of palm trees for their oil (most of the demand for which is unrelated to biodiesel at present) is already creating environmental impacts in Southeast Asia. The draining, deforestation, and burning of peat lands for palm cultivation is responsible for severe increases in carbon dioxide emissions in the region. In Indonesia, 44 million acres of forest have been cleared for palm plantations.[12] As a result, by 2007 Indonesia had become the world's third largest emitter of carbon dioxide, according to a study by Wetlands International and Delft Hydraulics, both based in the Netherlands.

Besides the possibility of exacerbating climate change, the use of large portions of the planet's arable land for fuel raises serious environmental and economic justice questions. To the degree that total cropland is decreased and not replaced by conversion of other land, the world's food supply could fall, raising food prices and damaging living standards, particularly in low-income nations.[13] On the other hand, the Worldwatch Institute has argued that higher prices for crops benefit poor farmers, who have been harmed by U.S. and European crop subsidies that lead to low prices.[14]

In regard to impacts on food supplies, most researchers expect cellulosic biofuels to yield much better results than corn ethanol and soy biodiesel, since they do not necessarily depend on diverting food crops to fuel. If cellulosic fuel comes from materials such as wood waste or from sustainably managed grasslands and forests, emissions due to land use changes could be insignificant. But much will remain unknown about the impacts on land use until such fuels are produced on a large scale.

Dr. Delucchi developed the LEM model to estimate lifecycle greenhouse gas emissions from fuels. As of this writing, the model is incomplete and Delucchi's research is ongoing. He did, however, present preliminary results to the California Air Resources Board in June, 2007, stating a broad range of uncertainty in the numbers. Delucchi estimated that corn ethanol could yield between a 25% decrease and a 20% increase, soy biodiesel between a 20% decrease and a 50% increase, and cellulosic ethanol between a 75% decrease and a 40% decrease in greenhouse gas emissions. Besides indirect land use changes, Dr. Delucchi also highlights the importance of the analysis of non-carbon dioxide greenhouse gases, including nitrogen dioxide and ammonia.[15]

Other recent analysis conducted by researchers at the University of California–Berkeley on behalf of the California Air Resources Board finds that indirect land use impacts could dominate all other factors in the carbon lifecycle of crop-based biofuels.[16]

Table 2.1 above summarizes the UC-Berkeley research. Accounting for indirect land use changes dramatically alters the greenhouse gas equation, causing the overall results for crop-based ethanol and biodiesel to be worse than for petroleum-based gasoline or diesel fuel (although, as discussed below, the petroleum fuel numbers do not include indirect impacts).

Table 2.1: Greenhouse Gas Impacts of Biofuels, Direct and Indirect					
Grams CO2 equivalent/megajoule energy output					
	Gasoline	**Midwest Corn Ethanol**	**Calif. Ultra Low Sulfur Diesel**	**Canola Biodiesel**	**Renewable Diesel (Palm)**
Direct Emissions	94	88	93	32	21
Indirect Emissions from Land Use Change		140 (CRP*) to 540 (tropical rainforest)		1,031 (tropical rainforest**)	197
Total Emissions	**94**	**228 to 628**	**93**	**1,063**	**218**

*CRP is the U.S. Conservation Reserve Program, through which marginal agricultural land is kept out of production.

**Indirect impacts from use of canola biodiesel (the primary feedstock in Europe) are much higher than for palm biodiesel per gallon of fuel, even though both may cause tropical rainforest conversion to palm trees, because palm trees yield several times more oil/acre than canola (rapeseed).

In terms of direct emissions, which don't include the full spectrum of possible land use changes, corn ethanol produces on the order of 20% less greenhouse gas emissions than gasoline, while biodiesel results in one-third the emissions of petroleum-based diesel. But when land use changes are added to the equation on the biofuels side, corn ethanol produces at least twice as much greenhouse gas as gasoline, while biodiesel produced from U.S. feedstocks could be 10 times as large a greenhouse gas producer as petroleum diesel.

It should be recognized that these are worst-case results, since they assume that converting one acre of food crops for fuel results in converting an additional acre of uncultivated land to food crops. To the degree that the global demand for food falls as prices rise (with possibly harmful effects on human welfare) or productivity per acre increases, land use impacts would be reduced.

Also, it is important to recognize that the studies discussed above, and the U.S. Department of Energy's GREET model, have not analyzed the indirect lifecycle impacts from extracting and refining petroleum on land use and possibly other factors. Greenhouse gas emissions and other environmental costs from petroleum are likely to increase as oil is increasingly extracted from more difficult sources, such as Canadian tar sands. Analysts have estimated that, on a full lifecycle basis, use of tar sands results in about one-fifth more emissions per gallon of fuel than conventional gasoline.[18] This is because, although most emissions due to oil take place when the fuel is burned during consumption, greenhouse gas emissions during extraction and refining of oil from tar sands are three times as high as those from producing conventional gasoline, according to one study.[19] In addition, tar sand extraction involves heavy use of water and land degradation.[20]

Analysis along the same lines as that conducted by Dr. Delucchi and by the UC-Berkeley researchers was recently published in *Science* magazine, showing similar results. The authors found that while, based on the GREET model, corn ethanol yielded a 20% reduction in greenhouse gas emissions versus gasoline, accounting for indirect land use changes resulted in a 93% increase in emissions. Furthermore, they argued that high levels of biofuels production from crops could lead to increases in the prices of corn, wheat, and soybeans.[21]

The U.S. Department of Energy, which developed the GREET model, the New Fuels Alliance, and several other groups have responded to the *Science* article taking issue with both the methods and results. They argue several points: (1) that the primary assumption of 30 billion gallons per year of corn ethanol (five times current use and twice the amount called for by federal law by 2022) is far too high, creating potentially amplified land use impacts; (2) that the treatment of yield increases is inaccurate; (3) that their assumptions about what kind of land would be converted is pessimistic; and (4) that the full lifecycle impacts of petroleum have not been included in the calculations.[22, 23]

Dr. Wang, the primary developer of the GREET model and author of the U.S. DOE response to *Science*, further claimed that there is no indication that corn exports from the U.S. have declined, which makes the core of the argument that foreign lands are being converted premature. And Dr. Delucchi of UC-Davis stated, "[i]n sum, these studies highlight an important (and generally well known) effect of the development of biofuels, but leave out a great many important factors, and do not tell us anything definitive about the overall impact of biofuels on climate."[24, 25]

The *Science* article authors have responded to the critiques of their analysis.[26] They note, for example, that one reason corn exports have not fallen is because U.S. acreage planted in corn rose 18% from 2006 to 2007, in response to ethanol demand and higher prices.[27] In turn, soybean acreage fell sharply. The authors of the UC-Berkeley study and the Science article are also of the opinion that indirect petroleum impacts on land use will be relatively small compared to those for biofuels.[28] Several studies are currently investigating the indirect impacts of petroleum production, including, but not limited to, land use.

As this debate shows, the scientific research on these questions is unsettled at present. Clearly, the indirect greenhouse gas impacts (including, but not limited to, land use) from petroleum should be calculated and included in any comparison of fuel sources, and the results of research in this area should be included in Massachusetts's regulatory framework as they become available (see discussion of a Low Carbon Fuel Standard, Chapter 4).

While comparing alternatives based on projected future emissions impacts is important, one primary goal is to cut greenhouse gas emissions from current levels. The Energy Independence and Security Act of 2007 defines "renewable fuel," "advanced biofuel," and "cellulosic biofuel" as meeting percentage lifecycle greenhouse gas reductions in relation to a "baseline" representing average emissions from gasoline or petroleum diesel fuel in the year 2005—not in relation to a future scenario in which oil shale or tar sands are dominant sources of supplies.[29]

If it turned out that petroleum from shale oil or other highly damaging future sources has higher emissions than crop-based biofuels, but that crop-based fuels raise emissions relative to current gasoline and diesel fuel, then neither fuel source would be acceptable from a climate change perspective. Instead, we would need to strengthen our focus on other solutions, including electric vehicles, vehicle efficiency, emerging low carbon fuels (if available), and reducing vehicle miles traveled.

Importantly, most analyses to date project that cellulosic-based biofuels will yield major reductions in greenhouse gas emissions relative to current petroleum fuels. The analyses include those of Dr. Delucchi, the U.S. Department of Energy, and the U.S. EPA, all discussed above.[30]

How best to evaluate the full lifecycle impacts of alternative fuel sources—particularly relating to land use—is a new and evolving field. None of the results published so far are definitive, and further research is being done by California, the U.S. EPA, the European Union, and various academic researchers. Much of this research will not be available until the end of 2008 or later. Until a scientific consensus is established, much will remain uncertain about the greenhouse gas impacts of biofuels and all other fuels, including petroleum, over the course of their lifecycles.

Biofuels derived from cellulosic materials, such as cellulosic ethanol, promise much greater reductions in greenhouse gas emissions than do food-crop biofuels such as corn ethanol—and with fewer environmental costs.

> UMass-Amherst, MassHighway, the Massachusetts Water Resources Authority and the City of Boston all use thousands of gallons of biodiesel blends from 5% to 20% in their fleets every year—with no adverse effects on their vehicles, resulting in significant reductions in carbon monoxide, particulate matter, and sulfates, as well as hydrocarbon and air toxics emissions.
>
> —*Massachusetts Leading by Example Program, EEA*

Criteria Air Pollution, Water Pollution, and Water Use

Greenhouse gas emissions are not the only environmental impacts of both fossil and renewable fuels. Burning fuel results in emissions of various other pollutants and biofuels should be compared with petroleum-based fuels on this basis as well. In addition, there could be far-reaching environmental impacts of withdrawing water from potentially stressed water sources. Wastewater impacts also require adequate analysis.

Air Pollution

Blending ethanol with gasoline at low levels as an oxygenate (as is done in Massachusetts to comply with reformulated gasoline requirements) uses ethanol in, at most, a 10% blend (E10) in place of MTBE (an additive that caused water pollution problems). E10 decreases most air pollutants, such as carbon monoxide, yielding significant public health benefits. Ethanol can, however, exacerbate hydrocarbon emissions due to its volatility at low percentage blends. For E85, most analysis indicates that criteria air emissions are generally similar to those for gasoline.[31] One study, however, suggests that use of E85 could raise formaldehyde and acetaldehyde levels nationally, and ozone levels in some regions of the country.[32] Since cellulosic ethanol is chemically identical to ethanol from food crops, air emissions from burning it are expected to be the same as from use of corn-based fuel.

The manufacture of ethanol is regulated much like a chemical plant because it emits VOCs (volatile organic compounds), which are precursors to ground level ozone and air toxics such as acetaldehyde. These air pollutants are tightly regulated in Massachusetts because the state does not meet national health-based standards for ozone. Depending on the size of a facility, the level and complexity of potential air quality emissions will vary.

Biodiesel combustion results in reduction of most air pollutants (particulate matter, carbon monoxide, hydrocarbons, sulfates, and air toxics) compared with petroleum diesel, according to current EPA testing, but causes some increase in nitrogen oxides (a precursor to smog) when used as a motor vehicle fuel in higher level blends.[33] Further research is being conducted due to conflicting data, since other rigorous studies have shown no increase in nitrogen oxides or a decrease when compared to burning diesel.[34] However, when used in combination with Number 2 oil as a heating fuel, nitrogen oxide emissions do not rise and may fall, while emissions of other pollutants are reduced significantly.[35] [36]

The potential use of waste material, including construction and demolition debris and other urban waste, municipal solid waste, sewage sludge and other waste feedstocks in the production of biofuels raises concerns over releases of heavy metals and other contaminants. More information is needed to understand and evaluate the potential effect of such uses on human health and the environment.

Water Pollution

Biorefineries require water to convert biological materials into fuel and this water must be treated and discharged as a waste product.

Corn production requires large amounts of nitrogen, phosphorus, and pesticide inputs, as well as fertile land. These fertilizers and pesticides can be transported by leaching and surface flow to surface, ground, and coastal waters, resulting in eutrophication, loss of biodiversity, and elevated nitrate and nitrite levels in drinking water.

Because biodiesel crops use smaller amounts of fertilizer, pesticides and water in production compared with corn, their impacts on water supply and quality are much less significant.[37] Waste products include glycerin and about one gallon of water discharge for each gallon of biodiesel produced. There is a market for the glycerin byproduct as animal feed, anaerobic digestion enhancement, and potential use at wastewater treatment plants to accelerate denitrification. Since the byproducts of biodiesel and ethanol have value, new refining processes are being used to maximize recovery. Wastewater from biodiesel refineries can be high in grease and oils resulting in a biological oxygen demand that can damage aquatic environments if not properly treated.

Cellulosic ethanol feedstock can be produced with little or no fertilizer or pesticides and requires less water than other biofuel crops. Cellulosic biorefineries do, however, have brine discharges and the production process produces wastewater that can kill aquatic life unless adequately treated before it is discharged.[38]

As with any manufacturing plant, ethanol plants and biorefineries have the potential for spills and leaks during the refining process and from chemical and product storage tanks.

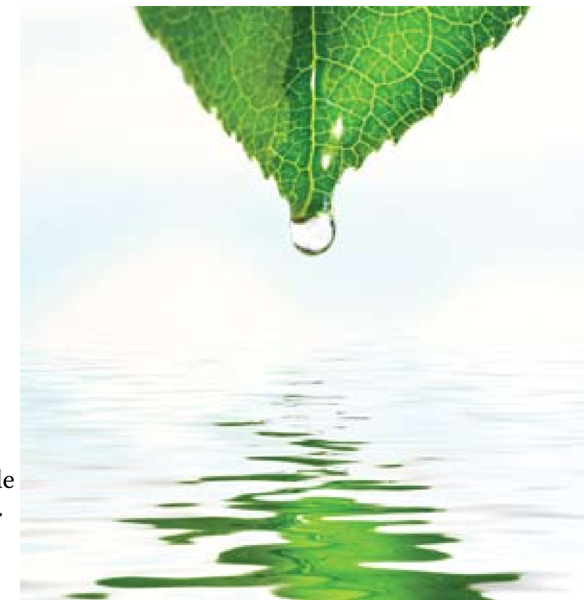
Water Use

Ethanol production consumes water through evaporation during distillation and for cooling towers. Cellulosic ethanol can consume two to six gallons of water per gallon of ethanol produced, while corn ethanol production consumes four gallons of water per gallon of ethanol.[39]

Biodiesel refineries proposing to locate in Massachusetts have described limited water withdrawal needs for the refining process, since they have selected new technology that reduces water consumption. Water at these facilities is mainly used as tank wash water or to mix with concentrated acid or alkaline catalysts for the refining process (one company estimates 0.1 gallon of water per gallon of biodiesel in their refining process), with some water demand for heating or cooling.[40] Other sources claim a demand of one gallon of water per gallon of biodiesel.[41] It is important to note, however, that petroleum extraction and production also require large volumes of water.

Policy Recommendations

The European Union's experience in alternative fuel policy illustrates the need for care in choosing which feedstocks and biofuels to use and which deserve government support. The EU mandated that, by 2010, biofuels should represent 5.75% of all transportation fuels as part of a larger agenda of increasing the ratio of renewable energy in the domestic energy supply.[42] Subsequently, lifecycle analysis made it clear that biofuels vary in their impact on carbon emissions.



As a result, European countries are now in the process of creating a certification protocol to require that biofuels have a certain percentage lower emissions than conventional fuel to qualify for government subsidies. For example, Sweden has proposed that biofuel would have to produce 40% less greenhouse gas emissions than conventional fuel to qualify for government support. Other proposals aim to prohibit the import of biofuels grown on certain types of land, such as wetlands or rainforests. Such regulations would primarily affect palm producers in Southeast Asia and sugarcane producers in Brazil.[43]

Seeking to avoid problems encountered in the European experience, federal energy legislation recently passed by Congress, the Energy Independence and Security Act of 2007, does address the connection between land use change and greenhouse gas emissions, requiring that, to qualify for the production mandates established by the law, biofuels must meet specific direct and indirect lifecycle greenhouse gas emission reduction targets. For first-generation biofuels (primarily corn ethanol) the requirement is 20%; "advanced biofuels" (including biodiesel) must meet a 50% reduction target; and cellulosic fuels must be 60% below petroleum.[44]

Both the California Air Resources Board (as part of developing regulations for its Low Carbon Fuel Standard) and the U.S. EPA (as part of developing regulations to enforce the greenhouse gas and land use requirements in the federal energy law) are in the midst of intensive efforts to evaluate the lifecycle impacts of all fuels that could power motor vehicles.

In view of these efforts, the Massachusetts Advanced Biofuels Task Force recommends the following:

1. Develop standards for lifecycle evaluation that consider the carbon and environmental impacts of biofuels, including potential impacts on agricultural, forest, and other land use in Massachusetts and on a global basis, using definitions similar to those employed in California and included in the new federal energy law. These evaluations must include both direct and indirect impacts, as well as consideration of impacts on environmental justice. Due to the complexity of lifecycle analysis, to the extent possible, Massachusetts should make use of analyses done by other parties, including the California Air Resources Board, the U.S. EPA, and the European Union.

2. Lifecycle evaluation methods should put biofuels, petroleum fuels, and other energy sources for vehicles (such as electricity and hydrogen) on a level playing field, assessing secondary and indirect impacts for all.

3. To receive state support for biofuels development and/or use, a particular biofuel must provide a substantial reduction in greenhouse gas emissions relative to petroleum fuels on a lifecycle basis.

4. The state should ensure that developers of refineries meet stringent water discharge limits and select technologies that reduce water needs.

5. Since biofuels made from in-region waste materials, such as waste oils, are likely to have lower greenhouse gas emissions than biofuels from virgin materials, state agencies should have the latitude to exempt fuel produced from waste materials from a full lifecycle greenhouse gas emissions analysis. However, state agencies should require a review that considers the highest reuse option for the waste feedstock (including recycling) and conduct appropriate environmental reviews of biofuel production processes that seek to minimize potential air and water impacts, as well as chemical and energy use.

6. Support the development and implementation of fuel quality standards (for example, federal ASTM standards) to provide consumer assurance of reliability of advanced biofuels.

Chapter 2 Endnotes

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Chapter 3:
Biofuel Feedstocks—Energy Crops, Biomass, and Waste Products

While Massachusetts will never be a source for fossil fuel extraction or production, it does have potential to provide feedstocks for the production of advanced biofuels. Developing the infrastructure, markets and production facilities to use local agricultural feedstocks (such as switchgrass), sustainable forestry feedstocks, agricultural waste (such as cranberry waste), and other waste streams (such as paper sludge, sawmill waste, etc.) has the potential for economic development in the agriculture, R&D, and manufacturing sectors. In addition, such development would provide both greenhouse gas reduction and fuel security benefits.

This chapter presents an overview of the feedstocks within Massachusetts that are available to support production of biofuels. These feedstocks are generally woody cellulosic materials and waste materials, for example, derived from the organic component of municipal solid waste (MSW), that can be used to produce ethanol, and waste oils and greases that are source material for biodiesel and other liquid biofuels. The table below provides a summary of the potential supplies of these feedstocks, which are described more fully in the subsequent sections.

The potential production of cellulosic ethanol, from the feedstocks within the state, totals to about 156 million gallons a year, which is 6% of the 2.67 billion gallons per year of gasoline that the state consumed in 2006. Importantly, this same feedstock is also under consideration by state policymakers and developers for renewable

Table 3.1. Sustainable Annual Potential Massachusetts Feedstocks and Biofuel Production[1]

Source	Supply		Energy	Biofuel Production* (million gallons)	
	Green Tons	Dry Tons	Trillion BTUs	Ethanol	Biodiesel
Energy Crops (cellulosic)					
Farmland (20% substitution)	201,000	163,000	2.8	13.0	
Idle Farmland	179,000	145,000	2.5	11.6	
Woody Residues and Forest Biomass					
Western Massachusetts (5 counties)	1,256,000	657,000	11.3	52.6	
Surrounding Counties from bordering states	9,300,000	4,866,000	83.7	389.3	
Waste Products					
Organic Components of MSW**	1,862,000	980,000	16.9	78.4	
Restaurant Waste Oils/Grease	29,000				6.4
Wastewater Grease	42,000				1.5

* Assumes conversion of 80 gallons of ethanol per dry ton biomass; and 80% and 10% conversion efficiencies for restaurant and wastewater production of biodiesel, respectively.

** Calculated as organic component of MSW waste-stream that currently goes to landfills, plus 50% of volume that currently goes to trash-to-energy facilities, minus 50% of the paper volume, which is assumed diverted to recycling at higher rates than at present.

energy power and thermal applications. Additional feedstocks from agricultural wastes, such as those generated by cranberry processing, have not been included. Use of such wastes for biofuel may become valuable for the state's agriculture sector, providing a new revenue stream for growers, and should be encouraged by state policy. But these wastes are unlikely to make a substantial contribution to the overall feedstock volume available for conversion to biofuels.

Energy Crops in National and Regional Context

The term "energy crop" refers to plants grown specifically as feedstock for energy production—either for fuel for heating and power plants, or for processing into biofuels. Since energy crops are typically cultivated on agricultural lands that might otherwise grow food, direct and indirect impacts on land use and the environment must be considered (see Chapter 2). Corn and soybeans are the dominant energy crops grown in the U.S. for ethanol and biodiesel production, respectively. In the Northeast, recent attention has focused on switchgrass and willow (salix) as cellulosic energy crops for heat and power.

The U.S. Departments of Energy and Agriculture have supported programs to study and demonstrate energy crops—particularly switchgrass, willow, and hybrid poplar. Oak Ridge National Laboratory in Tennessee hosts the Bioenergy Feedstock Information Network[2] and offers a model to assess the economic opportunities for energy crops on a state-by-state level.

Regionally, New York State has a lead role in the commercialization of willow, under the leadership of the State University of New York's College of Environmental Science and Forestry in Syracuse.[3] Several hundred acres of commercial willow plantations in New York are providing biomass fuel for co-firing in coal power plants, and the state also has an intensive bioenergy research agenda.

In Vermont, the state university is engaged in a one-year pilot project to assess the potential for production and processing of oil-seed and sugar-containing crops for use as a renewable energy source on a scale suitable for local farmers.[4] Site trials have been performed on two farms in Shaftsbury, VT, and initial findings suggest that canola and sunflower have the best potential as oil-producing crops for the Vermont region.

The Connecticut Agricultural Experiment Station[5] has also investigated canola and soybeans, while the University of New Hampshire Cooperative Extension[6] has experimented with a number of sunflower varieties.

Energy Crops in Massachusetts

In comparison with other states, Massachusetts is not a large agricultural producer. Nonetheless, prospects for growing energy crops in the Bay State are of interest because of the potential benefits derived from diversifying our agricultural sector, keeping marginal or threatened agricultural lands in production and of providing income from open lands not currently in agricultural production.

Several important developments—centered largely on efforts at the UMass-Amherst—have recently increased understanding of the potential for energy crops in Massachusetts.

Switchgrass Site Trials: In 2006, 12 varieties of switchgrass were planted by the UMass Plant and Soil Science Department at the South Deerfield agricultural experimentation station. Based on productivity studies over the 2007 growing season, significant differences were determined among the varieties, and several were identified as worthy of further investigation. The site trial is located in some of the best agricultural soils in the Commonwealth, so further evaluation is needed in a range of soil conditions where energy crops might have economic potential.

Energy Crop Potential Study: As part of the Massachusetts Sustainable Forest Bioenergy Initiative led by the state Division of Energy Resources and Department of Conservation and Recreation, the UMass Department of Resource Economics completed a preliminary study in January 2008 of the potential for energy crops in the Commonwealth.[7] The study examined switchgrass and willows based on cost and productivity data from Oak Ridge National Laboratory and the UMass site trials, compared energy crop costs with costs of woody biomass fuel from residues and forestry, and analyzed the acreage of lands potentially available for energy crop production. The results of this study are provided later in this chapter.

Crambe Research and Development: *Crambe abyssinica*, an Abyssinian mustard, is an industrial oil crop that has enormous potential as a low input source of renewable cellulosic biomass for bioenergy and biodiesel production. Crambe is an ideal biodiesel feedstock, with seed oil content of 40% to 50%. Native to the Mediterranean region, crambe is a non-food, cool season, non-invasive crop that has been domesticated and grown commercially in the U.S.—particularly in colder regions—since 1990. Following initial commercial production in North Dakota with support of the U.S. Department of Agriculture, U.S. cultivation of crambe peaked in 1993 at nearly 60,000 acres, but diminished after the federal support was ended.

In addition to its high seed oil content, crambe is well suited for biodiesel due to the high level of erucic acid (60%-67%) in its seed oil. Erucic acid is a heat stable, long chain fatty acid that is a critical raw material of industry as an additive to lubricants and solvents, plasticizers, high temperature hydraulic fluids, pharmaceuticals, cosmetics, and other products. Crambe has also been used for remediation of sites contaminated with toxic metals and is productive in marginal soil conditions.

Dr. Om Parkash, an Assistant Professor in the Department of Plant, Soil, and Insect Sciences at UMass-Amherst, is a leading national researcher on crambe who has developed the genetic transformation system for the plant enabling genetic modifications to enhance the plant's ability to produce oil and grow in marginal lands.[8]

The Institute for Massachusetts Biofuels Research: The Institute for Massachusetts Biofuels Research (TIMBR) is a multi-disciplinary research consortium at UMass dedicated to increasing the use of biomass for energy and fuel. Through a recent National Science Foundation award, Institute researchers in chemical engineering are engaged in refining a range of feedstocks into biofuels: biodiesel, bio oil, methanol, cellulosic ethanol, and others.

Potential for Energy Crops in Massachusetts

The University of Massachusetts Department of Resource Economics recently completed a study[9] evaluating the potential for biomass energy crops in the Commonwealth. Performed as part of the Massachusetts Sustainable Forest Bioenergy Initiative,[10] the study was limited in its scope, focusing on willow and switchgrass potential in the five westernmost counties. It analyzed expected crop production prices and considered three sources of land for growing energy crops: replacing crops on existing farmland with energy crops; planting energy crops on idle farmland; and converting forested land to energy crops.

Both switchgrass and willow can grow in Massachusetts with yields expected to be four to five times as great as biomass yields from

The potential production of cellulosic ethanol from feedstocks within the state totals about 156 million gallons a year, which is 6% of the 2.7 billion gallons of gasoline that the state consumed in 2006.

forestlands (40-55 million BTU per acre for switchgrass and willow compared with 10 million BTU per acre for forests).

The study revealed that the cost of producing energy crops is difficult to determine. Nevertheless, existing models were used to establish cost estimates. The results suggest that energy crops are reasonably close to competitiveness with forest-derived wood chips. For delivered fuel to a biomass energy plant, cost for willow and switchgrass was determined to be $32 per ton and $68 per ton, respectively, compared with $31 per ton for forest-derived wood chips. Taking into account the difference in moisture content, the findings suggest costs of $3.69 per million BTU and $4.94 per million BTU for willow and switchgrass, respectively, compared with $3.32 per million BTU for forest-derived wood chips. Processing switchgrass into fuel pellets requires additional costs but provides a premium fuel product that would compete with wood pellets. This study notes the speculative nature of the price estimate for the energy crops, and the sensitivity of these prices to soil conditions, cultivation and harvesting operations and further progress on crop yields.

The UMass researchers also looked at potential lands that could be devoted to growing energy crops and the total energy contribution that could be realized. Considering the current land in active agriculture in the five westernmost counties, if 20% (67,000 acres) were converted to energy crop production, an estimated 2.8 trillion BTUs of energy could be supplied. This energy represents 5.3% of the potential demand for biomass fuel, as calculated by the researchers to supply energy for residential and commercial heating and an expected build-out of 165 MW of biomass electric power. If all idle farmland (60,000 acres) were put into production of energy crops, an additional energy yield of 2.5 trillion BTUs could be realized, representing 4.7% of the potential demand for biomass.

Researchers did not consider the use of marginal and open lands not in agriculture, but those lands could also provide significant production. The integration of energy crops into the state's Agricultural Preservation Restriction program could be useful to maintain open space and working landscapes on qualifying lands where available labor and economics call for lower intensity farming activity.

Energy crops generally require less intensive cultivation than conventional crops, especially after a plantation is first established. As energy crop research and development progresses in Massachusetts, water demand and pesticide use should be carefully evaluated.

Algal Biofuels

High lipid algae—the subject of federal research from 1978 to 1996—is a promising source for future production of biodiesel and other biofuels.[11] Depending on the species, algae contain 20% to 40% lipids by weight. Lipids are oils that make these algae well suited for conversion into biodiesel. Algae also have high growth rates and can be harvested daily, giving them an advantage over conventional sources of biodiesel such as soybeans, which are harvested annually. Algae also have a much higher yield per acre than conventional biodiesel sources, producing between 5,000 and 20,000 gallons per acre per year. The source with the next greatest yield, oil palm, only produces 635 gallons per acre per year. Moreover, algae do not require soil for growth and can be located on non-agricultural land, thereby avoiding some of the direct and indirect land use impacts associated with other biofuel sources.

The extraction of oil from algae for conversion into liquid biofuels is already well documented. Liquid biofuels such as biodiesel produced from algae is sulfur- and toxin-free, and highly biodegradable. In addition, the use of carbon dioxide emissions from power plants to grow algae is now being championed by a number of start-up companies, notably GreenFuel Technologies Corp. of Cambridge.[12]

Despite these advantages, a number of technological and engineering challenges must be overcome before algae-based biofuels can become a commercially viable alternative to conventional diesel or heating oil. The cultivation of algae can only occur under specific light, temperature, and density conditions. Waste oxygen created in the growth process must be continually removed. In addition, open algal ponds are subject to evaporation and rainfall that can create salinity and pH imbalances and local species of algae can overgrow the desired strain.[13] It will also be necessary to more fully understand the molecular biology of algae and the manipulation of molecular switches that cause increases in oil production in order to commercialize algae biodiesel. As a center for biotechnology research and business, Massachusetts is well positioned to develop and benefit from this technology.

Woody Biomass from Residues and Forests

Woody biomass is a substantial cellulosic feedstock in Massachusetts that can be used for local production of cellulosic ethanol once that technology becomes available. Woody biomass comes either from residues from current economic activities or from sustainable forest management. Residues include wood wastes from forest products industries, trees removed for land development, tree trimmings from parks and utility line maintenance, and a large fraction of construction and demolition debris. In Massachusetts, forest biomass resources come from active forest management, which must conform to strict sustainable forestry regulations established under the Massachusetts Forest Cutting Practices Act. This forest management should be consistent with sustainability certification provided by the Forestry Stewardship Council and provide timber harvesting that enhances the forests' ecological and economic value.

The Commonwealth's Division of Energy Resources and the Department of Conservation and Recreation are engaged in the Massachusetts Sustainable Forest Bioenergy Initiative which has assessed the woody biomass resource potential and economic impact of a biomass energy economy. The Initiative will establish a strategic plan for developing the supply chain infrastructure needed to bring this fuel to the market.

The woody biomass resource assessment[14] is focused on the five western counties of Massachusetts, as well as surrounding counties in bordering states. The assessment determined that the sustainable supply of woody biomass from residue sources is roughly 630,000 green (inclusive of water content) tons per year, and capable of expanding to 3.6 million tons per year inclusive of the surrounding states.

The Sustainable Forest Bioenergy Initiative is primarily focused on biomass for electric power and thermal energy. The potential translates into 100 MW of sustainable electric generation capacity from Massachusetts-based resources, expanding to nearly 700 MW inclusive of the supplies from the surrounding counties of bordering states.

The availability of woody biomass for conversion to liquid biofuels will depend on the competitive ability to pay for fuel in the electric, thermal, and fuel markets. The current price for delivered wood chips to biomass energy plants is \$25-\$35 per green ton.

A biofuels industry would have significant impact on the rural Massachusetts economy, benefiting 500 licensed foresters, 60 sawmills, thousands of secondary manufacturers, and numerous landowners. The industry would also provide high paying jobs to rural Massachusetts workers including plant operators, technicians, and engineers.

—A Report of the UMass Clean Energy Working Group, February 2008

Developing the infrastructure, markets and production facilities to use local agricultural feedstocks (such as switchgrass), sustainable forestry feedstocks, agricultural waste (such as cranberry waste), and other waste streams (such as paper sludge, sawmill waste, etc.) has the potential for economic development in agriculture, R&D, and manufacturing. In addition, such development would provide both greenhouse gas reduction and fuel security benefits.

Biofuels from Organic Waste Feedstocks

Waste organic products can also be used as feedstocks for the production of biofuels. With processing, wastes that are high in oil content can meet standard specifications for commercial fuels such as heating oil and transportation diesel. The potential supply is limited, but using these feedstocks is likely to yield substantial greenhouse gas reductions and may offer an environmentally superior method of disposing of these wastes. One study found that "biodiesel and bioethanol routes are generally energy intensive…[but] in the case of biodiesel from waste vegetable oil, the energy balance is more favorable, with the energy in the biodiesel estimated at between 6.6 and 8 times that of the non-renewable energy input."[15] Another study found similarly positive results for use of waste animal fats.[16]

A greater variety and volume of wastes, including the organic components of municipal solid waste, can potentially be used as feedstock for cellulosic fuel, although the technologies for converting them are currently in development. Great care must be exercised to ensure that the ultimate waste byproducts of the fuel production process are disposed of properly. In particular, the potential use of waste material, including construction and demolition debris, organic components of municipal solid waste, sewage sludge, etc. in the production of biofuels raises concerns over releases of heavy metals and other contaminants. More information is needed to understand and evaluate the potential effect on human health and the environment of such uses.

Appropriate waste products include:

- Vegetable oils and animal fats from restaurants and commercial food processing facilities,
- Sludge or grease derived from wastewater and the treatment of wastewater,
- Animal byproducts, including poultry fats and meat processing wastes,
- Agricultural wastes, including residues from cranberry processing, and livestock waste, and
- Organic components of municipal solid waste, including mixed paper, food waste, and yard waste.

The processing of waste into biodiesel that meets American Society for Testing and Materials (ASTM) standards (necessary for use in automobile engines or home heating systems) requires considerable sophistication and rigorous testing to ensure quality control. Although not yet ASTM-certified fuels, other biofuels that can compete with petroleum for use in generating heat or power are produced by several companies.

Waste vegetable oil and animal fats are feedstocks used by the only company in Massachusetts that currently produces biodiesel in significant volume, MBP Bioenergy. This Massachusetts biodiesel plant illustrates that while biofuels are easier to produce from virgin vegetable oils, waste feedstock has important economic advantages, and avoids many of the negative environmental impacts that result from the disposal of waste oils and the use of virgin feedstocks.

The U.S. Department of Energy estimates that the restaurant industry generates a volume of waste oil equal to nine pounds per person annually.[17] Based on this figure and our state's population, approximately 6.4 million gallons of biodiesel could be made in Massachusetts annually if this waste were processed into this biofuel. Collection, however, poses problems. Small volumes are generated at many distributed locations, requiring waste to be collected in "milk runs" that increase costs and reduce the greenhouse gas benefits of the resulting fuel.

The same U.S. Department of Energy report estimates that the nation's wastewater contains about 13 pounds of grease per person annually. In Massachusetts, this figure implies that approximately 1.5 million gallons of biodiesel per year could be produced from this waste, but once again, collecting it results in costs for transportation and pretreatment, which may reduce potential environmental and economic benefits. Municipalities require restaurants to pump out grease traps regularly, but if this clean-out does not occur or if facilities have not installed a grease trap, wastes are discharged directly into municipal sewer systems not designed to treat them. Grease trap waste is a contributor to sewer system overflows,[18] creating expensive clean-up problems.

Much larger volumes of organic waste are potentially available from municipal solid waste (MSW) for conversion into cellulosic fuel. Use of the organic portion of MSW could also help address waste disposal problems, after waste streams have been minimized through reuse and recycling wherever feasible. Proactive steps should be taken to prevent a strong market for the use of organic MSW components as feedstock from acting as a disincentive to recycling and reuse.

Solid waste can be processed into biogas, and then liquid biofuels, through gasification, fermentation, pyrolysis, and anaerobic digestion. There are numerous challenges to creating usable biofuels including issues related to the high level of contaminants and water in the feedstock.[19]

As of 2006, approximately 3.5 million tons of MSW were sent to landfills (both in- and out-of-state) or combustion facilities, after large portions of the waste stream were diverted to recycling and composting. At present, much of the waste goes to combustion facilities under long-term contracts, but these contracts will expire over time and full development of the cellulosic industry is not assumed to occur until 2025 (see Chapter 1). In addition, it is hoped that an increased fraction of the paper waste can be recycled, through improved recycling programs. For purposes of estimating the feedstock available for cellulosic fuel, we have assumed that all the organic material currently going to landfills, plus half of that going to combustion facilities, will be available. From that combined total we then subtract half of the paper waste, assuming that it goes to recycling. The remainder is approximately 1.9 million tons of wet or "green" material, yielding 980,000 dry tons.[20]

Policy Recommendations:

Note: A variety of tax and other state incentives have the potential to support the development of advanced biofuel feedstocks in the Commonwealth. Recommendations relating to this are discussed in detail in Chapter 6.

1. Conduct additional field trials and commercial demonstrations of biomass crops in Massachusetts to determine optimal crops, production methods, and costs for the state. Trials on marginal agricultural land and other working landscapes are of particular interest. Evaluation of these trials should include environmental impacts (including carbon emissions and soil sequestration) and infrastructure needs for planting, harvesting, and transporting materials.
2. Expand the preliminary UMass study on economic potential of energy crops in Massachusetts to include other crops and non-agricultural marginal lands and to improve yield and cost assumptions. Develop a spatial model illustrating potential lands that may be conducive to biomass crops.
3. Support development work (genomic and breeding) on energy crops such as crambe and switchgrass to improve crop yields and biofuel production.

Crambe abyssinica, an Abyssinian mustard, is an industrial oil crop that has enormous potential as a low input source of renewable cellulosic biomass for bioenergy and biodiesel production.

4. Explore opportunities to promote algae production by the Massachusetts aquaculture industry and bioengineering research at Massachusetts companies and universities.

5. Conduct an internal review of all state agricultural preservation and assistance programs for the purpose of integrating energy crop production into the programs. Explore the benefit of establishing capacity at the state Department of Agricultural Resources and UMass Extension to provide outreach and training to farmers and other landowners interested in establishing early commercial plantations.

6. Complete the current work of the Massachusetts Sustainable Forest Bioenergy Initiative on woody residue and forest biomass feedstock and consider in its strategic plan the potential use of this feedstock for production of cellulosic ethanol.

7. Encourage and work with the federal government to support biorefinery technologies and demonstration projects that can be developed on smaller scales to utilize locally available fuel, including waste feedstocks.

8. Investigate the feasibility and design of a statewide program to collect and transport waste vegetable oil and grease trap waste to biofuel production facilities from Massachusetts restaurants and institutional kitchens. The investigation should consider the needs of the existing infrastructure for collection, transportation and processing these wastes, and the use of technical assistance, incentives and mandates to accomplish these goals.

9. Due to the inherent environmental benefits of reusing waste products over virgin sources of biofuels, give state environmental agencies the authority to reduce or provide exemptions from greenhouse gas emissions lifecycle analysis requirements when applied to biofuels produced from waste feedstocks.

10. Further investigate the applicability of cellulosic waste materials including the organic fractions of municipal solid waste, paper sludge, and construction and demolition debris for cellulosic ethanol production, while maintaining strict regulatory controls to ensure that no increases in toxics or other pollutants takes place.

Chapter 3 Endnotes

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Chapter 4:
Statutory and Regulatory Mandates, Regulatory Flexibility

The Commonwealth's objective is to develop a biofuels policy that grows the clean energy sector through in-state R&D and production, enhances the environment, and provides economic security by reducing petroleum use and dependency.

The potential economic and environmental benefits of biofuels argue for consideration of regulatory and financial incentives to promote their development and production in Massachusetts. Financial assistance (grants, loans, and tax policy) is discussed in Chapter 6. This chapter focuses on regulatory methods by which the state might encourage the production and use of biofuels in an environmentally beneficial manner.

There are two basic regulatory approaches for encouraging alternatives to petroleum-based fuel used principally for transportation and secondarily for space heating:

1. content mandates for fuel purchased or sold; and
2. a Low Carbon Fuel Standard, which sets overall limits on greenhouse gas emissions but does not mandate the content of any specific fuel or technologies used.

Both approaches move us away from petroleum and toward lower-emission, renewable fuels. The Low Carbon Fuel Standard, however, does so in a way that is technology neutral, allowing the market to drive the development of alternative fuels at lowest cost. Although content mandates offer important benefits in the short run, in its hearings across the state the Advanced Biofuels Task Force heard strong support for moving toward a Low Carbon Fuel Standard as the means of promoting innovative solutions to our fuel needs.

Content Mandates

The federal Energy Independence and Security Act of 2007 requires "renewable fuel" used in the U.S. to rise from 4.7 billion gallons in 2007 to 36 billion gallons in 2022, "advanced biofuel" to rise from 0.6 billion gallons in 2009 to 21 billion gallons in 2022, and cellulosic biofuel to rise from 0.1 billion gallons in 2010 to 16 billion gallons in 2022. Renewable fuels must be produced from renewable biomass, replace other transportation fuel, and achieve at least a 20% reduction in greenhouse gas emissions on a lifecycle basis for "new facilities." (Expansion of existing facilities is exempt from the greenhouse gas criterion.) Advanced biofuel excludes ethanol derived from corn starch, and must yield at least a 50% lifecycle reduction in greenhouse gas emissions, while cellulosic biofuel must achieve a 60% reduction. The law contains provisions allowing the EPA administrator to reduce both the percentage greenhouse gas reductions and the volumes of production required. The three categories are not additive—cellulosic fuel counts as part of advanced fuel, and both count as part of the renewable fuel mandate.[1]

Mandates for use of E85 fuel (85% ethanol) have been passed in some states, mainly ones where corn is a significant local crop. Iowa has a renewable fuel standard that requires

Governor Patrick's *Leading By Example* Executive Order, signed April 18, 2007, instructed state agencies to switch to 3% biobased fuels for all use of Number 2 heating oil, beginning with the winter of 2007-08. The Order requires 10% biofuels by 2012.

10% of motor fuel in the state to be replaced by ethanol and biodiesel in 2009, rising to 23% in 2018. Oregon requires gasoline to be blended with 10% ethanol, but only after in-state ethanol production reaches 40 million gallons a year. Similarly, Louisiana law requires that 2% of gasoline consist of ethanol from in-state feedstocks, but only once in-state production reaches 50 million gallons per year.

Biodiesel mandates have also been passed by some states, but generally go into effect only when in-state production of the fuel is sufficient to meet mandated demand. Biofuel mandates in the Northeast and Mid-Atlantic states are more limited —generally restricted to fuel use by state fleet vehicles.

Biodiesel mandates have also been passed by some states, but generally go into effect only when in-state production of the fuel is sufficient to meet mandated demand. In Louisiana, diesel fuel is required to contain 2% biodiesel once in-state production reaches 10 million gallons. Minnesota requires that all diesel fuel contain 2% biodiesel, without regard to in-state production. Oregon will require 2% biodiesel once supplies from the Pacific Northwest (Oregon, Washington, Idaho, and Montana) reach 5 million gallons a year; the requirement rises to 5% once supplies reach 15 million gallons a year. Washington State will require a 2% biodiesel blend once in-state feedstocks are sufficient to meet the requirement, rising to a 5% blend once in-state feedstocks reach 3% of supply.[2]

Biofuel mandates in the Northeast and Mid-Atlantic states are more limited—generally restricted to fuel use by state fleet vehicles, in large part due to federal requirements for state fleets under the 2005 Energy Policy Act. New York has extensive policies, but these were recently re-evaluated in light of concerns over the lifecycle greenhouse gas impacts of particular fuels. A task force led by New York's lieutenant governor has indicated that policies will be put on hold pending development of a comprehensive biofuels strategy.[3] At present, New York requires that state vehicles use E85 whenever possible, and that at least 10% of fuel used in the state fleet be biodiesel by 2012.

Connecticut requires at least 50% of new cars and light-duty trucks in the state fleet to use alternative fuels, increasing to 100% in 2012. Rhode Island requires 75% of state vehicle acquisitions be vehicles powered by alternative fuel, fulfilling this requirement mostly by compressed natural gas-fueled vehicles. New Jersey requires all new buses bought by NJ Transit to be powered with alternative fuels, and Maryland requires state-owned flex-fuel vehicles to use at least 50% alternative fuel.[4]

In Massachusetts, Governor Patrick's "Leading By Example" Executive Order, signed on April 18, 2007, instructs state agencies to use 3% bio-based fuels for all heating that currently uses Number 2 heating oil, beginning with the winter of 2007-08, and 10% biofuels by 2012.[5] Implementation of the Order is under way, but full information on compliance by state agencies is not yet available.

Administration and Finance Bulletin #13, issued August 11, 2006, instructs the Executive Office of Administration and Finance and the Division of Energy Resources to set minimum percentage requirements for state agency use of E85 in state-owned flex-fuel vehicles. It also sets requirements for use of biodiesel blends in state diesel vehicles, beginning at 5% in Fiscal 2008 and increasing to 15% in Fiscal 2010. Current reporting indicates that the requirements are only being partly met due to lack of available fuel. Bulletin #13 also says that 3% biodiesel blends will be used in heating oil in state buildings, with waiver provisions.

Legislation filed on November 5, 2007, by Governor Patrick, along with Senate President Therese Murray and House Speaker Salvatore DiMasi, would provide support for cellulosic ethanol and biodiesel. Cellulosic ethanol would be exempted from the state's gasoline tax (see further discussion in Chapter 6), while minimum requirements would be set for use of biodiesel blends in both diesel motor fuel and Number 2 heating oil sold in the state. B2 (2% biodiesel) would be required beginning in July 2010, ramping up to B5 in 2014. The Division of Energy Resources would have authority to delay the implementation dates based on "lack of supply, lack of blending facilities, or unreasonable cost." Biodiesel supplies meeting the mandate would have to come from sustainably grown feedstocks, as determined by the Division. [6]

Various concerns have been expressed in relation to the proposed biodiesel mandates, including the lack of distribution infrastructure in the state (see Chapter 5); possible price impacts on consumers for both diesel transportation fuel and home heating fuel; possible shortages of oil-crop feedstocks that meet the greenhouse gas reduction criteria (see Chapter 2); impacts on small distributors, particularly in the home heating fuel sector[7]; and that by supporting a particular fuel it does not meet the technology-neutral principle of a Low Carbon Fuel Standard. In relation to the last concern, New Generation Biofuels, a Houston-based company currently developing a facility in Massachusetts, testified that the bill would not recognize the advantages of its product, which is designed to be used in 100% ("neat") form rather than blended with petroleum diesel.[8] The Massachusetts Oil Heat Council, however, has stated its support for a biodiesel content requirement for heating oil.[9]

A variety of measures could address the above-stated concerns. One option would be to provide state support for installation of biodiesel distribution infrastructure (see Chapters 5 and 6). Another, more complex option that could address several of these issues including difficulties for small distributors, would be to create a "cap and trade" system, under which fuel supplied in the state would have to meet the mandated biodiesel percentages on average, but not every gallon sold would have to do so. Suppliers who exceed the mandate—say, by selling B20 fuel—could sell "credits" to suppliers who don't have any biodiesel in their products. New Generation Biofuels would benefit under this scenario by having large numbers of credits available to sell, making their product more economical and helping to bring it into widespread use—precisely the point of a market-based regulatory system. Such a system would move Massachusetts in the direction of a Low Carbon Fuel Standard, though in this case only with regard to diesel fuels. However, it would add substantial complexity to the regulatory process, including oversight of participating companies—a cost that must be carefully considered.

Low Carbon Fuel Standard

The state of California has developed a Low Carbon Fuel Standard, which puts all non-petroleum vehicle fuel sources on an equal footing—not just biofuels, but also electricity and hydrogen fuel cells.

The Low Carbon Fuel Standard results from California's overall mandate to reduce greenhouse gas emissions (to 1990 levels by 2020 and 80% below 1990 levels by 2050), codified in Assembly Bill 32, and from an Executive Order creating the Low Carbon Fuel Standard as one method to achieve the goals of this legislation.[10] The fuel standard mandates that the "carbon intensity"—lifecycle greenhouse gas emissions per unit of energy delivered—of vehicle fuel in California be reduced 10% by 2020. This does not necessarily guarantee that total vehicle greenhouse gas emissions will fall, since increases in total use of fuel could cancel out reductions in carbon intensity.[11]

The California Air Resources Board is currently in the midst of developing regulations to implement the Low Carbon Fuel Standard. It is anticipated that the requirement would be imposed at the "top" of the consumption chain, on importers or distributors of petroleum fuel into the state. The Low Carbon Fuel Standard would not require every gallon of fuel used in the state to have 10% lower carbon content.

Rather, it would require that all fuel used in the state result in 10% lower emissions. Thus, a fuel distributor could meet the requirement by selling some cellulosic ethanol, which, over its lifecycle, is estimated to yield 60% lower greenhouse emissions per unit of delivered energy than gasoline, while continuing to sell mostly gasoline. Moreover, the Board is looking to implement the Low Carbon Fuel Standard as a "cap and trade" system. This is analogous to the Northeast's Regional Greenhouse Gas Initiative for electric power plants.

Professor Daniel Sperling of the University of California-Davis, who co-authored California's studies on the Low Carbon Fuel Standard and is now a member of the California Air Resources Board, testified at the Advanced Biofuels Task Force's hearing on January 17, 2008. He argued that there is great uncertainty concerning which technologies will prove to be the "winners" for powering motor vehicles and that Massachusetts should adopt a technology-neutral policy, creating a durable framework for the state and industries to rely on when making investment decisions. Dr. Sperling spoke against providing mandates for particular fuel options and testified that state incentives should be performance-based, related to the amount of greenhouse gas reduction a technology provides.

At this time, it is uncertain which fuels and other power sources will best fulfill the Low Carbon Fuel Standard. That is appropriate for a policy designed to stimulate the competitive marketplace to yield the most economical method of meeting greenhouse-gas and petroleum-use reduction goals. It is possible, for example, that using biomass to generate electricity, which then powers vehicles through the use of plug-in hybrid cars and trucks, will be more effective at reducing greenhouse gases than converting the biomass into liquid fuels. California's technical study finds that as much as half of its 10% reduction in carbon intensity could be met with electric-drive vehicles.[12] Table 4.1 shows a range of strategies identified for meeting California's fuel standard.[13]

California does not know at this time whether there is enough biomass and other renewable energy available to fulfill its 10% reduction

Table 4.1: Possible Low Carbon Fuel Strategies

Low Carbon Fuel Strategy	Description
E10 (10% ethanol, 90% gasoline by volume)	Increase blending of ethanol from today's 5.7 percent average by volume to 10 percent.
E85 (85% ethanol, 15% gasoline by volume)	Sell high blend ethanol (85 percent ethanol, 15 percent gasoline) for use in flex-fuel vehicles.
Switch to Low-Carbon Ethanol	Switch to ethanol made from cellulosic materials (e.g., agricultural waste, switchgrass) that have 4-5 times lower GHG emissions than today's corn-based ethanol.
Electricity	Pure battery electric vehicles or plug-in hybrid vehicles that can be recharged from the electricity grid.
Hydrogen	Used in zero-emitting fuel cell vehicles or internal combustion engine cars modified.
CNG, LPG	Compressed Natural Gas and Liquefied Petroleum Gas burned in modified internal combustion engine cars.
Other biomass based fuels	For example, BP and DuPont are developing biobutanol as a possible additive and Chevron is exploring petroleum-like products synthesized from biomass (so-called "biocrude")
Other?	Future strategies to be developed by fuel providers and outside innovators.

requirement. It is also unknown whether an equivalent target, or a different one, would be achievable through a Low Carbon Fuel Standard in Massachusetts or throughout the Northeast.

What is clear is that a Low Carbon Fuel Standard, while constituting a "mandate" for reducing petroleum use in powering vehicles, does so in a technology neutral manner that lets the market identify opportunities to meet the mandate at lowest cost. It therefore has lower risk of failing to achieve its goals or of imposing high costs than do mandates that specify usage of particular fuels such as ethanol or biodiesel, or other specific technologies such as all-electric or fuel-cell vehicles.

Besides California, other states and some Canadian provinces are considering adoption of a Low Carbon Fuel Standard or have already done so. In 2007, the provinces of Ontario and British Columbia signed agreements to join California in implementing its fuel standard.[14] Florida Governor Charlie Christ has voiced intentions for his state to adopt such a standard.[15] In December 2007, at a conference sponsored by the National Governors Association, regional caucuses put forth recommendations for policy on biofuels, vehicle efficiency, and reducing vehicle miles traveled. A priority recommendation from the Mid-Atlantic/Northeast caucus was adoption of a Low Carbon Fuel Standard, and the Southwest/Midwest caucus stated as a priority "develop[ing] a low-greenhouse-gas vehicle program..."[16]

It is widely agreed that adoption of a Low Carbon Fuel Standard on a regional basis could be more effective and impose lower regulatory costs in each state (and possibly Canadian province) involved than would separate laws in one or more states. Fuel refiners and wholesale distributors, on whom the emissions requirements would probably be imposed, supply fuel on a regional basis, with distribution flows commonly going between states at the retail level. It could be challenging to track the average carbon content of fuel going to a single state. In addition, there could be substantial "leakage" problems if one state attempted to do a Standard on its own, as distributors shifted higher-carbon supplies to neighboring states that lack a Standard. Given the growing biofuels industry in the Commonwealth, Massachusetts can take a leadership role in developing a regional Low Carbon Fuel Standard.

In the Northeast's cold climate, where space heating is a major energy-use sector and a major source of greenhouse gas emissions, it might also make sense to move beyond California's vehicle-only Low Carbon Fuel Standard to treat equally all the possible uses of biomass as an energy source. Besides powering vehicles by conversion into a liquid fuel or used to generate electricity, biomass can also be made into a liquid fuel substitute for heating oil or as a solid fuel burned directly for space heating. In the spirit of technology neutrality, public policy could encourage the use of biomass on a performance basis, rewarding reductions of greenhouse gas emissions whether they occur in the transportation sector or in home heating. Such an expansion of the Low Carbon Fuel Standard could yield lower-cost emissions reductions and help make Massachusetts a pioneer in the economy-wide regulation of greenhouse gas emissions.

Improvements to Regulatory Flexibility

There are a number of technologies being developed to chemically, mechanically, or biologically produce advanced biofuels from waste feedstocks, where shift of land use from food to fuel is not an issue and so the risks of large carbon releases are minimized (described more fully in Chapter 3). Technologies span the full continuum of development from research facility to pilot scale production to commercially viable facilities.

With a Low Carbon Fuel Standard, government will not pick winners. Fuel providers will choose how they reduce the carbon intensity of their products, from options such as blending low-carbon biofuels into conventional gasoline, selling low-carbon fuels such as hydrogen, or buying credits from providers of other low-carbon fuels (such as low-carbon electricity or natural gas). This allows businesses to identify new technologies and new strategies that work for them and for their customers.

—Alex Farrell and Daniel Sperling, "Getting the Carbon Out," San Francisco Chronicle, May 18, 2007

Technology developers seeking to show that they can meet performance standards, produce fuels that meet specifications, demonstrate technical and economic feasibility, or optimize operating conditions may seek to operate for a limited time (usually less than one year) under pilot conditions.

Facilities desiring to test the use of advanced biofuels and blends will want to ensure that, for a temporary period, they can properly evaluate benefits, emissions, or operational and maintenance issues before making a fuel switch from petroleum based fuels. Therefore, making pilot demonstrations easy for interested facilities is important.

While many regulations allow these tests to occur for limited periods, a more comprehensive analysis and structure may be needed to encourage demonstrations and remove any barriers. Scaling up from pilot projects or operating for longer periods of time will require state agency review and permits.

Recommendations

1. Prioritize efforts to achieve near-term implementation of a regional, technology-neutral, and performance-based Low Carbon Fuel Standard (LCFS). Position Massachusetts as a leader in this regional development. Given the uncertainty of regional coordination, however, the Commonwealth should also move forward without delay in designing a Massachusetts-specific LCFS that other states and provinces can potentially adopt. The Standard should include lifecycle greenhouse gas reduction standards, as discussed in Chapter 2 of this report on Energy and Environmental Lifecycle, and should reward companies for performance-based results in achieving such reductions.

2. Consider incentives to promote the best uses of sustainably harvested biomass, whether as a replacement for transportation fuels or in other energy applications, such as a liquid fuel substituting for heating oil or as a solid fuel used directly for space heating and/or electricity generation. This would move the state closer to being technology-neutral, searching for the most cost-effective means of reducing petroleum use and greenhouse gas emissions.

3. While a Massachusetts Low Carbon Fuel Standard is being developed, implement transitional, carefully targeted mandates, such as requirements for minimum percentages of biodiesel in motor and heating fuel. Mandates should require that the fuels yield substantial lifecycle greenhouse gas reductions, including direct and indirect impacts such as those on land use, while not increasing the release of other pollutants; should be limited, such as by being tied to in-state production of the feedstocks and by phasing out as a Low Carbon Fuel Standard comes into existence. Mandates should be as flexible and technology-neutral as possible. Use of a trading system for meeting the requirements should be considered, although the regulatory complexities this would add must be weighed carefully.

4. The state should ensure that temporary, pilot scale biorefineries are allowed to proceed after review of appropriate environmental safeguards and evidence that the pilot's results will be useful if it succeeds. Analysis of potential contaminants contained in or produced from the processing of waste products such as construction and demolition waste, the organic fraction of municipal solid waste, and biosolids from wastewater treatment plants should be required. MassDEP should review its regulatory authority to determine whether revisions are needed to allow pilot scale waste-to-fuel production. MassDEP should assist in the review of pilot scale projects (whether or not they need a permit) to ensure that, when a proponent seeks approval for a commercial project, those permits can be issued in a timely manner.

5. The state should support the demonstration of operational, maintenance, and environmental impacts from the use of renewable fuels made from waste in commercial boilers or turbines. Funding for the purchase of biofuels and to oversee tests done at state facilities may be needed. State environmental agencies should adopt reasonable reporting requirements for those deciding to burn advanced fuels. The continued use of existing permitted fuel, if the advanced biofuel is unavailable, should be allowed.

6. Further research and analysis should be done to evaluate the benefits and costs of policies to support biofuels development through a regulatory framework, including those in (3) above, on an expedited timeline.

Chapter 4 Endnotes

1. "Energy Security Through Increased Production of Biofuels," Title II of HR6, "Energy Independence and Security Act of 2007, found at http://thomas.loc.gov.

2. "Custom Query" results from legislative database of the federal Department of Energy's Alternative Fuels and Advanced Vehicles Data Center, accessed January 2008.

3. "Clean, Secure Energy and Economic Growth: A Commitment to Renewable Energy and Enhanced Energy Independence," The First Report of the Renewable Energy Task Force to Lieutenant Governor David A. Paterson, State of New York, Feb. 2008.

4. From database of state biofuels incentives, developed by Economic Development Research Group for Massachusetts Advanced Biofuels Task Force (ABTF), version as of 2/14/2008.

5. "Executive Order 484: Leading by Example—Clean Energy and Efficient Buildings," Governor Deval Patrick, 4/18/2007.

6. House 4364, An Act Furthering the Biofuels Clean Energy Sector, filed November 7, 2007.

7. See testimony of Michael J. Ferrante on behalf of the Massachusetts Oilheat Council at the Jan. 17, 2008 ABTF hearing in Boston.

8. Testimony of Connie Lausten on behalf of H2 Diesel, at ABTF hearing in Boston, 1/17/08.

9. Michael Ferrante, President, Mass. Oilheat Council, testifying at ABTF hearing, 3/11/2008.

10. Executive Order S-01-07, by the Governor of the State of California, 1/18/2007.

11. See "A Low-Carbon Fuel Standard for California, Part I: Technical Analysis," and "Part 2: Policy Analysis," Alexander E. Farrell, Daniel Sperling, et al., May and August 2007.

12. "A Low-Carbon Fuel Standard for California, Part 1: Technical Analysis," Alex Farrell and Daniel Sperling, May 7, 2007, page 5.

13. "White Paper: The Role of a Low Carbon Fuel Standard in Reducing Greenhouse Gas Emissions and Protecting Our Economy : Executive Summary," California Air Resources Board, 1/9/2007.

14. "Ontario and California Sign Historic Accord On Low-Carbon Fuel Standard, Collaborate On Cancer Research," press release from Ontario Premier's Office, 5/30/2007; "Message from Environment Minister Barry Penner," British Columbia Ministry of Environment, Feb. 2007.

15. "Schwarzenegger Applauds Florida for Adopting California's Tailpipe Emissions Standards, Aggressive Environmental Protection Policies," press release from California Governor's Office, 7/13/2007.

16. "Securing A Clean Energy Future. Greener Fuels, Cleaner Vehicles: A State Resource Guide," National Governors Association, Feb. 2008, Table 7, "Top Participant Recommendations from Regional Breakout Session," page 27.

Chapter 5:
Promoting Infrastructure for Delivery and Distribution of Biofuels

Seizing the opportunity to make Massachusetts a national leader in the development and use of advanced biofuels will require improvement of infrastructure for biofuels delivery and distribution. In order to make biofuels a true alternative to petroleum products, consumers must be able to use them in their vehicles, homes and businesses. For advanced biofuels to transition successfully into a significant industry in the region, accommodations will be needed in the mechanisms by which Massachusetts meets its fuel needs. At present, such mechanisms in transportation, heating, and other uses are geared almost exclusively to the use of petroleum products and corn-based ethanol.

In 2006, Massachusetts accounted for about 2% (2.7 billion gallons) of the U.S. demand for gasoline (138 billion gallons), and 41% of New England's total gasoline demand (6.5 billion gallons).[1] Massachusetts is one of five states that use federal reformulated gasoline statewide, using a 10% ethanol blend (E10), which recently replaced the additive MTBE. This relatively low blend of ethanol adds to the oxygen content of gasoline, allowing it to burn more cleanly and reducing carbon monoxide and ground-level ozone emissions.

Diesel fuel is primarily used in the transportation sector, comprising about 89% of the 443 million gallons consumed in Massachusetts in 2006.[2] On-road diesel fuel must meet EPA's ultra low sulfur standards of not more that 15 parts per million sulfur. Since sulfur compounds serve a lubricating function in diesel fuels, ultra low sulfur diesel requires lubrication additives. Biodiesel and other biofuels in low blends could be added to diesel fuel as a premium lubricant, but are not yet in widespread use for this purpose.

Massachusetts consumed 638 million gallons of Number 2 heating oil in 2006. Residential customers, representing 39% of households in Massachusetts, accounted for 83% of this use. Commercial and industrial customers and some electric generators used the remainder. There are 600 to 800 heating oil dealers in Massachusetts, most of whom own their own delivery equipment and vehicles. Yet, there are relatively few heating oil suppliers in New England.

In the refining process, crude oil is heated until much of it becomes a gas, which when cooled condenses back to liquid form and, in the process, separates primarily into gasoline and distillate fuel oils, including diesel graded from 1 to 3. The heavy remaining oil is classified as Number 5 or, more commonly, Number 6 oil, and is also referred to as residual oil. The heaviest solids are used as lubricants, waxes, or asphalt.

Distillate fuels are used primarily for space heating (heating oil) and on- and off-highway diesel engine fuel (e.g. railroad engine fuel and fuel for agricultural machinery) and for electric power generation. Distillate fuel oil used by electric generators represents only about 1% of the total distillate fuel used. However, electric generators in 2006 accounted for about 63% of state use of the heavier Number 6 residual oil.

> While ethanol and biodiesel are both used almost exclusively in blends with petroleum, their supply chain and infrastructure needs differ significantly. Seizing the opportunity to make Massachusetts a national leader in the development and use of advanced biofuels will require improvement of infrastructure for biofuels delivery and distribution.

Number 4 oil, which is generally made by blending Number 2 distillate oil with Number 6 residual oil, is used primarily in industrial plants and commercial burners; this includes No. 4 diesel fuel, which is used for low- and medium-speed stationary boilers. Some have proposed substituting biodiesel for Number 2 oil to create "Bio Number 4."[3] Residual oil is used for production of electric power, industrial processes, and for marine vessel fuel.

Petroleum Supply and Distribution

Like the rest of New England, Massachusetts lacks crude oil production, refining capacity, and direct service by a major interstate petroleum pipeline. All petroleum products are imported from two main sources: domestic refined products, originating in the Gulf Coast, and imports supplied primarily by Canada, Venezuela, and the U.S. Virgin Islands.

Most of these products arrive in Massachusetts by marine shipments. Up to 90% of petroleum used here is imported via ship or barge. Several major ports—including Boston, Braintree, Weymouth, Quincy, and Fall River—receive and store petroleum products. The remaining 10% enters Western Massachusetts, most of it by petroleum pipeline or truck. One small product pipeline (owned by ExxonMobil) runs from the port of Providence to Springfield terminals and another (owned by Buckeye Partners) carries only distillate fuels and jet fuel from the port of New Haven into the Springfield area. Western Massachusetts also receives petroleum products by truck from New York and heavy residual oils by rail.

There are 13 major terminals and several smaller bulk terminals in Massachusetts, in addition to regional terminals in neighboring states, that distribute refined petroleum products—ranging from jet fuel to gasoline to home heating oil—to customers in the Commonwealth. Various terminals are equipped for the storage and distribution of different types of refined products. Regional terminals are equipped with specialized loading stations (or racks) that load refined products into tanker trucks for distribution to end users, such as retail gasoline stations, or individual homes, in the case of home heating oil.

Petroleum products move from storage terminals primarily by road. Tanker trucks that deliver gasoline and diesel fuel to retail stations often have several separate compartments, allowing trucks to carry different formulations of fuel (e.g., regular unleaded, premium unleaded, and diesel) to retail stations in a single trip. In the case of gasoline, the ethanol or special additives that are used to differentiate one brand from another are often blended into the gasoline in the tank of the delivery truck as it is loaded at a terminal. In some cases, fuel blend components are picked up at multiple

Table 5.1: Overview of Massachusetts Petroleum Demand

Population	6,437,193 (2006)
Total Energy Consumption	1.5 quadrillion Btu (2004)
Per Capita Energy Consumption	240 million Btu (2004)
Total Petroleum Consumption	5.7 billion gallons per year (2005)
Gasoline Consumption	2.7 billion gallons per year (2006)
Gasoline Stations	2,700 outlets (2006) or 1.6% of U.S. total
Distillate Fuel Consumption	1.33 billion gallons per year (2006)
Heating Oil Consumption	638 million gallons per year (2006)
On-road Diesel Consumption	393 million gallons per year (2006)
Off-road Diesel Consumption	49 million gallons per year (2006)

Source: Energy Information Administration, U.S. Department of Energy; U.S. Census Bureau terminals and rely on "splash-blending" in the truck en route to delivery. This approach is typical of biodiesel blends, as well as other additives that are mixed into diesel fuel and home heating oil.

Home heating oil is transported by either a tanker truck or a smaller truck, called a bobtail, that typically holds up to 3,000 gallons and delivers the product to homes. Homes, which have heating oil tanks as small as 250 gallons, are supplied on "milk runs" that generally cover a service area of no more than 35 to 60 miles.

Biofuels Transportation and Storage

While ethanol and biodiesel are both used almost exclusively in blends with petroleum, their supply chain and infrastructure needs differ significantly. Properties of both ethanol and biodiesel prevent them from being distributed by pipeline in unblended form. Ethanol is easily contaminated by water, and biodiesel picks up and dissolves residues deposited in the pipelines by other fuels.

As a result, ethanol is primarily transported by barge, but also by railcar and truck, to large regional petroleum terminals. In smaller volumes, pure biodiesel (B100) comes to small inland terminals in Massachusetts, mainly by railcar and truck. In the near future, larger amounts of biodiesel may come into the major terminals by barge, or potentially by pipeline in low blends, such as B5.

Terminals are mainly comprised of massive tanks, each one dedicated to a particular refined petroleum product. Switching tanks from one fuel use to another can be complicated. For example, gasoline tanks require a system to recover vapor and return it to a liquid state, while tanks for home heating oil do not. In some cases, switching or upgrading tanks may require approval from regulatory authorities. Newer, stainless steel tanks can usually accommodate any petroleum product, while older tanks may have higher switching costs.

High blends of biodiesel require heating and insulation in winter to avoid the risk of the fuel gelling. The temperature at which liquid fuels gel (cloud-point temperature) varies by biodiesel feedstock and blend. This adds a significant retrofit cost to existing tanks or, more typically, requires terminals to add new purpose-built tanks. The costs of adding or retrofitting B100 biodiesel storage and inline blending equipment are currently unclear as estimates vary by terminal and range from $100,000 to over $1 million. In the absence of this equipment, one potential alternative is to blend in the tank by taking delivery of B100 biodiesel and the petroleum base fuel at the same time. This presents some logistical challenges and limits the terminal to offering only one blend per fuel type.

The Pioneer Valley Railroad, working closely with the City of Holyoke and other partners, is actively pursuing development of an existing storage and transfer site to create a regional inland terminal to supply biodiesel to Western Massachusetts and the surrounding region. This terminal would utilize the railroad spur from Westfield to Holyoke, providing rail access from multiple feedstock suppliers to serve power generation and heating oil markets.

Infrastructure for Promoting Advanced Biofuel Supply

Besides the small and nascent waste oils collection business, biofuel feedstocks are generally not produced or refined in Massachusetts. Without more capacity to grow or refine biofuel feedstock, the Commonwealth could face a situation with biofuels not unlike its current situation with regard to petroleum products—reliance on imports that drain rather than boost the state's economy.

Nationwide, there has been rapid expansion in refining capacity for both ethanol and biodiesel, primarily located close to corn and soy feedstocks. The U.S. overtook Brazil to become the world's leading ethanol producer in 2005, and production capacity has continued to grow rapidly, reaching an annual production level of 8.2 billion gallons in March 2008.[4] This growth has been driven by the Federal Renewable Fuels Standard (RFS), which requires 9 billion gallons annually in 2008. However, much of the additional 5.2 billion gallons of annual ethanol refining capacity under construction in the U.S. is on hold due to prices for feedstock and uncertainty around near-term ethanol demand above the mandated RFS.[5] A similar mismatch between planned refining capacity and expected production is evident for biodiesel, with 450 million gallons produced in 2007 but annual refining capacity now over 2.2 billion gallons, including plants under construction or on hold.[6]

UMass–Amherst, MassHighway, the Massachusetts Water Resources Authority and the City of Boston all use thousands of gallons of biodiesel blends from 5% to 20% in their fleets every year, with no adverse effects on their vehicles – resulting in significant reductions in carbon monoxide, particulate matter, and sulfates, as well as hydrocarbon and air toxics emissions.

—Massachusetts Leading by Example Program, EEA

Limited rail and truck capacity has also complicated the delivery of ethanol, contributing to regional ethanol supply shortages and price spikes between April and June 2006 when a national phaseout of the gasoline additive MTBE required replacement of roughly 10 percent of the gasoline blend with ethanol.[7] Feedstock and product transportation costs and bottlenecks remain problematic for the biofuel industry, leading many biofuel producers to explore the prospect of locating near a dedicated feedstock supply or large demand center to minimize transportation costs. In this context, several initiatives to site refining capacity in the Commonwealth have recently emerged and are seeking to navigate a balance between the supply and demand constraints in this expanding market.

Wholesale Biofuels Refining in Massachusetts

Currently, MBP Bioenergy is producing 1 million gallons of biodiesel annually from waste vegetable oil and animal fats in Massachusetts for use in its own vehicles and blended with fuel oil (B20) for sale to heating customers—and this business is expanding. The waste is collected within 80 miles of their production facility in Southeastern Massachusetts, and the product has been used for over three years for year-round heating and transportation without problems.

Three other companies are now in the final stages of development for new biofuel refining facilities:

- **Berkshire Biodiesel** is in the design and permitting phase of a 50 million gallon per year biodiesel production facility in Pittsfield that will use variable feedstocks, including animal fats and waste and virgin oils;
- **Northeast Biodiesel** is developing a 10 million gallon per year biodiesel production facility in Greenfield that uses locally-produced waste vegetable oil feedstock and that features a unique project financing strategy that partners consumers with government, foundation, and investor resources;
- **New Generation Biofuels** is in the final planning stage to construct a second-generation biofuel production facility in Quincy using virgin and waste oils. Intended to be used in pure form, rather than blended with petroleum fuels, the New Generation Biofuels product appears to have an improved greenhouse gas profile relative to diesel and biodiesel as a transportation fuel or heating oil substitute.

Public Safety Concerns

As Massachusetts and the U.S. as a whole move to include ethanol as a possible alternative to gasoline, a public safety concern has come to light regarding ethanol fires. Water does not extinguish ethanol fires and the foam that firefighters have used since the 1960s to fight gasoline fires does not work well either. The main concern is not cars powered by E10, but tanker trucks and rail cars that carry large quantities of higher ethanol content E85 fuel. During the last three months of 2007, there were three major ethanol fires in the U.S. involving derailed tanker cars: in Pennsylvania; a tanker truck crash in Missouri; and a train derailment in Ohio.[8]

Addressing this concern may require fire departments to invest in alcohol-resistant, polymer-based foam, which costs about 30% more than the standard foam currently used by fire departments. Additional safety training for firefighters and other emergency workers would also most likely be needed as E85 becomes more widely used.

Facilitating Biofuel Use in Massachusetts

Biofuels can be used in a variety of ways to reduce the use of petroleum fuels. Facilitating the use of biofuels requires a range of infrastructure investments to make biofuel products more available to consumers, as well as increased consumer demand to make biofuel production and distribution more economically viable.

Gasoline and Its Alternatives

The standard gasoline product sold in Massachusetts is E10, a blend of 10% ethanol and 90% gasoline. Used as a blending component, ethanol is displacing 5% to 6% of gasoline consumption nationwide. The federal Energy Information Administration projects that between now and 2030 most of the first 16 to 20 billion gallons of ethanol produced per year nationwide will be used in E10. With current domestic production at 8-9 billion gallons a year, and a maturing market for E10 that could reach 16 billions gallons in the next several years, there appears to be room for cellulosic and corn ethanol expansion in the U.S. at this 10% blend, which would require no further modification of existing terminals, retail pumps, or vehicles.[9]

In addition, a recent study by the state of Minnesota reports that blends as high as E20 can be safely used without vehicle modifications.[10] Raising blends to E20 will require further testing and a U.S. EPA waiver, and in Massachusetts may depend on whether this blend can satisfy reformulated gasoline standards. Within the U.S. market, E20 approval could expand the market potential for ethanol (both conventional and advanced) to around 30 billion gallons per year.

According to the U.S. Department of Energy: "The market potential for low to moderate biofuel blends (E10, B5, and B20) remains significantly larger than current production levels and will continue to absorb the biofuel supply for the foreseeable future. "[11]

Higher blends of ethanol—typically labeled as E85 (although blends may be as low as 60% ethanol)—would require changes to many older retail station pumps and storage tanks and, equally significant, require a larger fleet of flexible-fuel vehicles (FFVs) to make the retail infrastructure economically viable. In the future, ethanol may face competition from other gasoline-alternative advanced biofuels such as biobutanol and biomethanol. Biomethanol has similar infrastructure requirements as ethanol, so investment in flex-fuel vehicles would benefit either fuel. But biobutanol more closely resembles petroleum diesel in its fuel properties and may not require infrastructure changes if and when it becomes a commercially viable fuel.

E85 Retail Station Pumps

Currently, there is only one retail E85 pump in Massachusetts, installed in Chelsea in 2007 by Dennis K. Burke Fuel and expected to open for commercial operation in Spring 2008.

To date, preliminary research suggests that fuel-switching an existing gasoline storage tank and associated dispensing pumps to E85 is difficult to justify due to the low number of flex-fuel vehicles in Massachusetts (precise data is not available, but for the U.S. as a whole they constitute less than 3% of the total). While the infrastructure costs associated with fuel-switching for a modern retail gas station would not be significant, lost revenues from a gasoline tank and pumps converted to dispensing E85 involve uncertain risk.[12] The alternative is for retail stations to add fuel tanks and pumps to offer E85 without losing gasoline capacity. This requires significant capital outlays for new tanks and pumps, as well as the space and permits to expand.

Recent Energy Information Administration estimates for replacing one gasoline dispenser and retrofitting equipment to carry E85 at an existing fueling station range from $22,000 to $80,000 (2005 dollars), depending on the scale of the retrofit. Some newer fueling stations may be able to make less extensive upgrades, with costs ranging between $2,000 and $3,000. The installation cost of E85-compatible equipment for a new station is nearly identical to the cost of installing standard gasoline-only equipment, but the anticipated demand for an E-85 pump may well be lower given the limited number of vehicles able to use it, and price uncertainties.

The financial risk inherent in building new E85 infrastructure at the retail level has deterred investment in Massachusetts to date. Given this difficulty, the state could:

- support local and regional pilot development efforts of flex-fuel vehicle clusters to develop a critical mass of support for retail E85 infrastructure; and
- provide limited financial support for selected E85 fueling stations, such as at rest stops along the Mass Turnpike, at MassHighway facilities, along I-95/128, along I-93, or along other heavily-traveled roads.

Flex-fuel Vehicles

For biofuel blends substantially higher than the current E10 to become a market choice, consumers will need to have vehicles available to them that run on those fuels. Flex-fuel vehicles (FFVs) are cars and trucks capable of running on virtually any blend of ethanol and gasoline up to E85.[13] There are currently about 6.2 million flex-fuel vehicles operating in the U.S., 2% to 3% of the 228.5 million light-duty vehicles on the road.[14]

It is relatively inexpensive to manufacture vehicles as “flex-fuel,” with additional costs averaging around $200 per vehicle. In Brazil, where sugarcane-based ethanol has been widely available for over a decade, most new cars are flex-fuel, with a wide variety of models on the market from manufacturers like Ford, GM, VW, Honda and Toyota. On the other hand, in the U.S. virtually all flex-fuel vehicles available for sale have large engines, making them relatively fuel inefficient models within their respective vehicle classes.

The reason for this appears to lie with the federal Corporate Average Fuel Economy (CAFE) vehicle efficiency standards. Both the existing and newly approved changes to the federal CAFE standards include a mileage credit for alternative-fuel vehicles. The result is that auto manufacturers get the greatest benefit from adding FFV capability to their most inefficient models. The U.S. Department of Energy’s annual energy outlook report for 2007 comments on this regulatory effect: “Although the incremental cost for vehicle manufacturers to make some models E85-capable at the factory is low (about $200 per vehicle), virtually all FFVs built since 1992 have been produced for the sole purpose of acquiring CAFE credits."

The fuel inefficiency of vehicles selected by manufacturers for flex-fuel technology is compounded by reduced mileage from E85 fuel due to ethanol's lower energy content relative to gasoline. As a result, mileage of flex-fuel vehicles ranges from 10 to 16 miles per gallon (mpg) when running on E85 fuel, with an average of only 11.5 mpg for 2008 models, according to the U.S. EPA.[15] When running on gasoline, FFVs average about 16 mpg, about 20% below the average for all light-duty vehicles sold in Massachusetts.[16]

Federal changes to the CAFE regulations or a federal mandate to incorporate flex-fuel capability across the vehicle fleet are needed to get manufacturers to produce high-mileage flex-fuel cars in large volumes. Nonetheless, as there is no technological reason why flex-fuel capability should only be available in low mileage models, Massachusetts might encourage regional or federal consideration of mandates or incentives for car manufacturers to supply flex-fuel versions of their more fuel-efficient vehicle models.

Flex-fuel choices are further limited in Massachusetts because not all manufacturers are submitting their full line of flex-fuel models to the California Air Resources Board (CARB) On-Road New Vehicle & Engine Certification Program.[17] CARB certification is a requirement for sale of new on-road vehicles in Massachusetts and several other Northeast states. As a result, only a sub-set of flex-fuel models are available for sale in the state. Chevrolet, for instance, offers most of its flex-fuel models for sale in Massachusetts, but Ford makes only a limited number of its models available to Massachusetts car buyers.

Current policy for the state-owned auto fleet calls for purchasing fuel-efficient hybrid and regular gasoline vehicles. These policies could be amended to require these vehicles, including hybrids, to be flex-fuel when available, as long as they do not result in state agencies purchasing cars and light trucks that are less fuel efficient than others available in the relevant vehicle classes.

Diesel and Heating Oil Alternatives

As with E10 gasoline, biodiesel has achieved initial acceptance in low-percentage blends such as B5, B10, or B20. Most diesel engine manufacturers have now approved B5 usage in their engines, with higher blends under consideration for future certification. Notwithstanding engine warranties, it is generally accepted that most diesel engines are compatible with biodiesel blends in excess of B5.

Similarly, in the heating oil market, low biodiesel blends have been successfully used for several years, and heating oil boiler and burner manufacturers are increasingly open to the use of B5 and higher blends in their new and existing equipment. Since blends as low as B5 typically take on the performance characteristics of 95% petroleum-based fuel, performance issues are minimal.[18] Although lubrication is improved, the cleansing properties of biodiesel can lead to an initial build up of residues on filters from dirty tanks.

It is anticipated that low blends of biodiesel could be incorporated into the diesel and heating oil supply chain without significant retail infrastructure costs. But additional infrastructure would likely be needed to provide the heated storage and blending equipment required at the 13 regional terminals to provide statewide coverage. Based on estimated retrofit costs of around $500,000 per terminal, this work would cost up to $6.5 million over five years. The investment could be amortized over five or six years with terminal operators

In Spring 2008, Dennis K. Burke Fuel Company is expected to open the state's first retail E85 fuel pump in Chelsea.

—Dennis K. Burke

New York City estimates 13 million gallons of B20 have been used by over 9,000 heating customers with no storage problems or issues with their home heating systems.

making use of federal accelerated depreciation tax benefits to mitigate their costs. A state investment tax credit could also be considered to provide further mitigation of costs, if needed.

A move toward blends of biodiesel above B20 to offset petroleum could be more straightforward than ethanol, since diesel engines are generally more accommodating than gasoline engines and biodiesel fuel is also less corrosive than ethanol. It is unclear how much, if any, additional cost vehicle manufacturers would incur to produce engines certified for high biodiesel blends. Meeting air quality standards could require additional testing and modifications to vehicles, given that much of Massachusetts has not attained the Clean Air Act standards for nitrogen oxides (NOx). There are existing private fleets running on blends ranging from B20 to B100, but there is no significant retail sale of this fuel in Massachusetts.

In addition to the use of Number 2 oil for residential heat, there is a significant market for heavier Number 4 oil in industrial process heat and electric power generation. Number 4 oil is a blend of at least 20% Number 2 oil with heavy Number 6 residual oils. It would be relatively simple to substitute biodiesel for Number 2 oil in this blend to create a Number 4 blend of approximately 20% biodiesel and 80% Number 6 oil, as an effective way to offset significant petroleum use in oil boilers and burners. Boilers and burners are generally cleaner burning than diesel engines, and while this blend would require testing and MassDEP approval, only minor modifications (if any) to equipment are anticipated.

There is significant potential for second-generation biofuels such as bioemulsions, Fischer-Tropsch (FT) diesel, and dimethyl ether (DME) to displace diesel and Number 2 heating oil fuels while meeting Clean Air Act standards and greenhouse gas mitigation criteria for advanced biofuels. While these second-generation biofuels are not yet commercialized in the U.S., there are production facilities under development, such as New Generation Biofuels in Quincy, and several other next-generation biofuels under development around the world.[19]

New Generation Biofuels' fuel is made from an emulsion of renewable oils, alcohols, and water and is touted as an alternative to diesel fuel that may not require any modification to Number 2 oil burners or diesel engines. FT diesel is produced by gasifying feedstocks such as biomass or coal and then using the Fischer-Tropsch gas-to-liquids technology. FT diesel can be mixed with petroleum diesel at any blend percentage without the need for additional infrastructure.

While initially targeted primarily at the heating and power generation sector, these next-generation diesel alternatives could likely also meet the tighter performance specifications required to run existing diesel engines, with the potential of providing up to 100% displacement of petroleum diesel or heating oil fuels. For this reason, a statewide average approach to a diesel mandate, rather than a requirement for a percentage blend in every gallon sold, would create a more level playing field for alternatives to petroleum-based diesel and heating oils.

Because these fuels have diverse chemical compositions and are new to the market, there are no established quality standards to protect users, as have been developed over time for biodiesel. Proponents of these fuels design batches to either meet generic or individual customers' performance requirements or to meet original engine manufacturer standards. Quality of the fuel is then measured using standard analytical test methods for individual parameters. Emissions profiles from the combustion of these fuels will likely need to be determined to ensure air quality standards can be met.

Other Alternatives to Petroleum Fuels

Fuel Efficiency

The most effective and efficient way to reduce dependence on liquid fuels, including both petroleum and biofuels, is through improvements in vehicle fuel efficiency. Reduced petroleum use also results from shifts of freight from truck transportation to the more fuel-efficient modes of rail and barge. Significant efforts by long-haul trucking manufacturers and fleet owners to improve truck fuel efficiency are now under way. And, in contrast to the limited sales of current flex-fuel vehicles, new highly efficient hybrid car models have become popular with Massachusetts consumers, despite a significant cost premium.

Improved fuel efficiency in vehicle design is compatible with the use of alternative fuels, but the two have rarely been combined by car manufacturers to date. Clear policy incentives at the state and federal level will likely be needed to promote the complementary benefits of fuel economy and fuel flexibility.

Natural Gas and Propane

The primary direct competition to date for liquid petroleum fuels in the heating oil and power generation markets has come from natural gas and, to a lesser extent, propane. Natural gas is cost competitive, distributed easily by pipeline, and has largely displaced fuel oil for new installations in both the heating and power generation markets.

For transportation uses, both compressed natural gas and propane powered vehicles have been in use for some time. Both of these fuels have been heavily constrained by a lack of fueling infrastructure and by limited and fluctuating availability of these vehicles from vehicle manufacturers. In Massachusetts, these limitations have restricted compressed natural gas transportation use to geographically discreet fleets such as transit buses, state vehicles, and propane vehicles in pilot use. The withdrawal from production of compressed natural gas pick-up trucks and passenger cars by the major U.S. auto manufacturers in recent years suggests that only bus fleets will continue to use natural gas in significant volume.

Since most current hydrogen fuel is created by reforming natural gas, and a natural gas pipeline infrastructure is already in place, future hydrogen powered vehicles will likely be dependent on natural gas fuel in the near term. As a result, hydrogen fueling infrastructure will likely face constraints similar to or greater than compressed natural gas.

Electricity

Electric-powered and plug-in hybrid vehicles represent significant future alternatives to liquid transportation fuels. Electrification enables vehicles to make use of mature and highly efficient electric motor technology and the mature infrastructure of electricity distribution. To date, electric vehicles have had limited range and battery life, but this will become less of an issue as battery technology improves. Plug-in hybrid vehicles have no range limits, since they can run on liquid fuels, including biofuels, as well as electric batteries. However, plug-in hybrids do require a secure garaging location to recharge, preferably during off-peak night-time hours, which presents a problem for many urban households. Otherwise, the infrastructure and fuel supply for plug-in hybrids is already in place, and—unlike current flex-fuel vehicles—electric and hybrid vehicles are the most fuel-efficient in their vehicle classes.

Electric, hybrid, and plug-in hybrid vehicles are also available and well suited to heavy

In April 2008, the Executive Office of Energy and Environmental Affairs issued requests for proposals to retrofit state-owned gasoline hybrid vehicles with plug-in technology. The plug-in hybrids, which can achieve up to 100 miles per gallon and reduce greenhouse gas emissions even more than regular hybrids, are expected to be in use by various state agencies later this year.

duty vehicle classes such as buses and local delivery vehicles, where the efficiency of electric motors at low speeds is an excellent complement to internal combustion engines, which operate more efficiently at higher speeds. By transportation mode, the most rapid increase in the share of total energy demand for transportation is projected in the heavy vehicle travel sector, making medium and large freight trucks and buses a critical area for fuel efficiency innovation. [20]

Recommendations

Future solutions to petroleum dependence in Massachusetts are still emerging, as is the role that the biofuels industry will play among the several potential alternatives to oil. In advance, and in anticipation of a regional Low Carbon Fuel Standard, interim policies promoting biofuels can catalyze in-state production and infrastructure investments. The state should give equal consideration to infrastructure for all alternative fuels and other technologies that meet environmental standards and lead to reduced dependence on petroleum. These include:

1. Implement limited-cost investments in infrastructure for ethanol and biodiesel, subject to budget constraints, such as E85 stations along major state highway corridors, and possible assistance for storage and distribution of biodiesel.
2. Study the benefits and costs of measures to increase the share of flex-fuel vehicles in Massachusetts, including mandates and incentives. Such research should take into account both short- and long-term impacts on actual greenhouse gas emissions and other environmental concerns. Explore policies to induce automakers to provide more fuel-efficient flex-fuel vehicle models than are currently available. For its own fleet, the state should purchase flex-fuel vehicles that exceed the average CAFE standard mileage requirements for each vehicle class.
3. Subject to state budget constraints, provide incentives to encourage development of smaller regional biorefineries, especially for cellulosic biofuels, that utilize locally-available fuel including waste feedstocks.
4. Support pilot deployment of plug-in hybrid and all-electric vehicles (including flex-fuel plug-in hybrid vehicles) in light-duty, medium-duty, and heavy-duty vehicle classes.
5. Investigate the costs and benefits of incentives for additional heated storage tanks and blending infrastructure at regional diesel terminals.
6. Support rail freight infrastructure for biofuels as part of a broader policy of promoting rail over road freight transportation.

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Chapter 6:
Grants, Loans, and Tax Incentives

As described in Chapter 1, aggressive expansion of a clean biofuels industry holds the promise of jobs and economic growth as part of a larger clean energy sector that capitalizes on Massachusetts's advantages in technology, venture capital, sustainable forestry and a highly skilled workforce. In addition, advanced biofuels offer the prospect of environmental benefits in the form of reduced greenhouse gas emissions as they displace the use of imported petroleum in our engines and furnaces. Reducing oil imports is also vital to the energy security of the U.S. as a whole. To realize this promise of global leadership, job creation and retention, economic growth, and environmental benefits, Massachusetts should begin rigorous benefit-cost analysis to identify the best financial tools to develop the sector. Such an effort must necessarily account for revenue impacts and direct and indirect environmental impacts.

As a general matter, state governments have the ability to use their own financial resources to aid particular industries whose growth they see as being in the public interest. Generally, the instruments at their disposal for this purpose include grants, loans, and the state tax code. Massachusetts has used these tools in recent years to provide targeted assistance in a number of areas, including for manufacturers, R&D companies, biotechnology, and the film industry. This chapter discusses the applicability of these options to the emerging biofuels industry, and makes recommendations about how to tailor state financial incentives to maximize the industry's potential in the Bay State.

At the outset, it is important to note that such policies must be considered carefully:

- investments should be made strategically, playing to the Commonwealth's comparative advantages in technology R&D, venture capital, sustainable feedstock sectors and a highly skilled workforce;
- the Commonwealth has limited financial resources and is currently facing a challenging budgetary situation;
- economic development incentives may or may not yield new tax revenues equal to their impact on the state's budget; and
- the broader benefits of particular subsidies, including jobs and environmental gains, must be analyzed in relation to their costs, so that these policies can be compared with other means of using state funds to achieve important goals.

Most existing federal and state-level biofuel subsidies and incentives are designated for first generation biofuels, primarily corn-based ethanol and soy-based biodiesel. Such policies are common in states with large agricultural sectors, but would offer few economic benefits in Massachusetts. This chapter will discuss these existing policies in other states, since available evidence on the effectiveness of subsidy policies relates mainly to them.

But "advanced," or cellulosic-based, fuels are more promising candidates for support from the Commonwealth, since Massachusetts has a greater ability to lead in the technological

Aggressive expansion of a clean biofuels industry holds the promise of jobs and economic growth as part of a larger clean energy sector that capitalizes on Massachusetts's advantages in technology, venture capital, sustainable forestry and a highly skilled workforce.

development of such fuels, and to supply feedstock for the production of these fuels locally.[1] Further, federal law now requires 21 billion gallons of advanced biofuel use per year by 2022, starting with smaller volumetric requirements in 2010.

Financial support for biofuels can be directed toward either companies or consumers. When directed at businesses, state incentives would make it easier for biofuel companies to locate, finance, and expand their operations here, creating jobs and economic opportunity. When directed at consumers, state incentives would stimulate demand for the industry's products, facilitating the growth of biofuel companies and capturing the benefits of lower greenhouse gas emissions and fewer petroleum imports. Separately or in tandem, state incentives for companies and consumers could help make advanced biofuels an integral part of the growing clean energy economy in Massachusetts.

Massachusetts is already home to many of the leading companies developing second-generation fuels and chemicals from biomass. It is critical for Massachusetts to attract and retain these businesses if the Bay State is to lead the global growth of the advanced biofuels sector.

This chapter reviews existing financial incentives for the development and use of biofuels in federal law, as well as those adopted by other states. It also discusses the existing financial support mechanisms for business development in Massachusetts that could benefit the biofuels industry, as well as biofuels-specific incentives that the Commonwealth might consider. Given constraints on the state budget, new financial incentives in the near term are likely to be limited, and will be best used to pursue opportunities that offer the greatest economic and environmental benefits at the lowest cost.

Existing Biofuels Incentives

At both the federal and state levels, biofuels receive a range of financial supports and incentives.

Incentives in Federal Law

Federal law currently offers large tax incentives for biofuels. A 51-cent excise tax credit is provided to oil companies for each gallon of ethanol blended into gasoline, while biodiesel from "virgin" crop sources is eligible for a $1 per gallon credit and biodiesel from waste oil gets a 50-cent credit.[2] The new federal energy law requires that a large portion of transportation fuel consumed in the United States come from biofuels in the future. Specifically, 15 billion gallons a year of corn-based ethanol is required by 2015 (the 15 billion gallon standard extends through 2022), and 21 billion gallons of "advanced" biofuels by 2022, of which 16 billion must be cellulosic. Additional federal incentives or requirements may be implemented to reach mandated levels of biofuel use.[3]

There may also be substantial R&D funding available, subject to federal appropriations, which could benefit Massachusetts and other states, as described in several sections of Title II of the Energy Independence and Security Act of 2007. This includes advanced biofuel production grants, R&D grants, cellulosic ethanol and biofuels research, bioenergy research centers, and renewable infrastructure grants.[4]

Incentives Adopted by Other States

Many states have adopted tax incentives for ethanol and biodiesel, including tax credits or deductions for production (about 20 states), investment tax credits for production facilities (about 10 states), excise tax exemptions, and infrastructure incentives (about 12 states).[5] In most cases, these states are large growers of corn or soybeans, and in some cases the incentives (or mandates, see Chapter 4) are linked to use of in-state feedstocks. For example, Washington State provides a tax deduction to companies on sale of biodiesel and E85 fuels. In Illinois, biodiesel blends from B1 through B10 are subject to sales tax rates 20% below that imposed on gasoline, while higher blends of biodiesel are exempt from sales tax altogether.

In the Northeast, biofuel incentives are less extensive, but several states do offer them. Of the 11 Northeast states, four have production tax credits or deductions and four have infrastructure incentives, while none have credits for investment in production facilities. Maine has a 5-cent per gallon income tax credit for in-state production of biofuels, but no company has claimed it to date. Maine also has a tax credit on the books for investments in biofuel pumps at retail gasoline stations, but it is unavailable at present due to a lack of state appropriations. Connecticut provides production payments for biodiesel producers, as well as a 50% tax credit for investments in compressed natural gas, liquefied natural gas, and liquefied petroleum gas filling stations. In Rhode Island, "organic" biodiesel is exempt from the motor fuel tax.

New Jersey's tax rate on liquefied petroleum gas and compressed natural gas is half that levied on gasoline. Maryland offers a tax credit of 20 cents per gallon for in-state production of ethanol made from grain, 5 cents if made from other products, and 20 cents for biodiesel made from soybeans at an in-state crushing facility.

Apart from fuels and infrastructure, several states provide incentives for purchasers of alternative-fuel or hybrid vehicles. Connecticut exempts compressed natural gas, liquefied natural gas, liquefied petroleum gas, hydrogen, and electric vehicles from the state sales tax, along with hybrids that are rated at 40 miles per gallon or more. New Jersey provides incentives of up to $4,000 for local governments that buy alternative-fuel or hybrid light-duty vehicles, and up to $2,000 for flex-fuel vehicles. New Jersey also exempts zero-emission vehicles from sales and use taxes.[6]

There are several tax and regulatory incentives in place in New York, including a tax credit of up to 15 cents per gallon for in-state biodiesel or ethanol production and reimbursement for up to 50% of the costs of installing fueling infrastructure, capped at to $50,000 per site. E85, CNG, and hydrogen are all exempt from state fuel taxes, and the tax on biodiesel is reduced. New York has recently announced a re-evaluation of its policies towards biofuels, however, and may reconsider its financial incentives. The state will conduct a study on the environmental and other impacts of particular feedstocks and develop a "roadmap" for state policy on renewable fuels.[7] On February 25, 2008, a task force on renewable energy led by the lieutenant governor issued a report stating, "Of particular concern is the current shortage of widely accepted environmental and public health data relative to emissions and land use impacts associated with renewable fuel use."[8]

State incentives for companies and consumers could help make advanced biofuels an integral part of the growing clean energy economy in Massachusetts.

The New York task force commented further that "current state policy on renewable fuels is not adequate and that no single renewable fuel will answer the increasing energy needs of the state. New York should address critical concerns regarding the specific fuels we may use—both to solve our energy mandates, and to prioritize environmental, land-use and health concerns in policy-decision making."

New York does, nevertheless, expect that re-focused policies will be valuable: "…[s]ince all of [petroleum] fuels are imported to New York, a substantial portion of the energy expenditures in New York is directed out of state. A carefully crafted renewable fuel policy can reduce this loss, enhance the environment, and create economic opportunities for New Yorkers."[9]

Biofuels And Economic Development in Other States

Existing state and federal policies to support first-generation biofuels have several goals: to aid domestic agricultural producers, reduce gasoline imports, and provide environmental benefits. Several industry- and state-sponsored studies have indicated that government subsidies can help bring about expansion of the industry, with large benefits in terms of jobs and in-state economic growth. A study for South Dakota, for example, estimated 3,000 jobs gained for the state, while one for Iowa, the largest corn-growing state, estimated 96,000 jobs.[10]

But these studies should be viewed with caution. First, their results for crop-dependent states may not be applicable to Massachusetts, where use of in-state feedstock is less likely. For example, one national study estimated that ethanol production created 195,000 U.S. jobs, but of these the vast majority were due to growing feedstock, with only 13,000 related to the operation of processing plants.[11] Another, more recent study estimated that, for a 100 million gallon per year ethanol plant, 50 people would be employed at the plant itself, but that total jobs gained in the state would be 1,790 (including a large multiplier effect).[12]

Given the need for society to cut emissions while minimizing economic costs, and the Commonwealth's limited financial resources, it is important to prioritize policies that yield the greatest emissions reductions per dollar.

Second, sometimes such studies exaggerate expected benefits relative to costs. For example, the more recent study referred to above estimated that $109 million in spending within the state related to a 100 million gallon/year plant (including growing feedstock) would yield $300 million in the state's economic output—implying an output multiplier of 2.75. Such a multiplier is appropriate at the national level, but is substantially overstated for state level impacts, where a higher percentage of indirect spending goes out-of-state (we use 1.9 as an output multiplier for Massachusetts in Chapter 1 of this report, based on results of the IMPLAN model).[13] Another study, for Minnesota, used a multiplier of 7.2 to convert from direct jobs to total jobs—far higher than the employment multiplier of 2.3 that we use for Massachusetts in Chapter 1 of this report.[14]

Studies from other states do shed some light on the efficacy of incentives: even if their multipliers and/or other forecasting parameters are not appropriate for Massachusetts, there will be economic gains from utilizing local feedstocks and from manufacturing fuel in the Commonwealth. The analysis presented in Chapters 1 and 3 estimates substantial economic benefits given a significant build-out of the advanced biofuels sector, based on the specific strengths and barriers involved in Massachusetts developing this industry. But clearly, more complete benefit-cost analysis is required. We have not, for example, forecasted the impacts of adopting particular incentive policies in the Commonwealth. Such analysis should be done in a rigorous manner in order for the Commonwealth to make decisions on the most cost-effective and efficient use of its limited budgetary resources.

Costs of Climate Benefits

New York's reconsideration of incentives on the grounds of cost and environmental effectiveness highlights a broader challenge in biofuels support: the costs of policies to reduce greenhouse gas emissions shouldered by both consumers and governments can vary greatly. Some analysts argue that current federal and state biofuels policies carry a high cost per ton of emissions reduced relative to other measures, such as fuel efficiency standards. This is not surprising as climate goals were not a driving objective during the formulation of the range of corn-based ethanol subsidies. However, given the need for society to cut emissions by a large percentage while minimizing economic costs, and the Commonwealth's limited financial resources, it is important to prioritize policies that yield the greatest emissions reductions per dollar.

At present, Massachusetts is focusing much of its energy policy efforts on improving the efficiency of buildings, products, and vehicles, all of which reduce greenhouse gas emissions at negative costs—meaning that they actually save consumers money. Massachusetts also supports renewable sources of electricity, using policies that favor the most cost-effective alternatives.

These include the state's Renewable Portfolio Standard, which allows electricity suppliers to meet minimum renewable energy requirements with the least-expensive eligible energy source available, and the Regional Greenhouse Gas Initiative (RGGI), which will use a cap-and-trade mechanism to let the market identify the most cost-effective means of reducing emissions. Forecasts for RGGI estimate that the high end of the cost to reduce carbon dioxide emissions is approximately $10 per ton, and is likely to be much lower. (The reserve price for the first auction of emissions allowances, in September 2008, is set at $1.86 per ton.)

If one looks at existing federal policies on biofuels solely in terms of expected reductions in greenhouse gas emissions and oil consumption, these policies appear to have much higher costs relative to their benefits than do the Massachusetts energy policies discussed above. A January 2008 paper written for the National Bureau of Economic Research by Tufts University economist Gilbert Metcalf estimated that the federal tax credit for corn-based ethanol cost U.S. taxpayers $1,700 per ton of carbon dioxide avoided in 2006, and reduced oil consumption at a cost of over $85 a barrel.[15] An earlier study done for the international Organization for Economic Cooperation and Development (OECD), which was critical of the high level of biofuel subsidies in its member states, estimated ethanol subsidies in the U.S. at $545 per ton of greenhouse gas emissions reduced and between $590 and $4,520 per ton in the European Union (depending on the country).[16] Testimony submitted to the Advanced Biofuels Task Force by Earth Track estimated that U.S. federal biodiesel subsidies total $1.80 to $2.20 per gallon.[17] Even if biodiesel eliminated 100% of the carbon dioxide emissions from petroleum diesel, this would be a cost of about $200 per ton of emissions.

Even these cost numbers per ton of emissions could be low, because the lifecycle greenhouse-gas reducing potential of crop-based fuels is uncertain at present and more definitive answers will probably not be available for a year or more (as discussed in Chapter 2). Without this information, it is difficult for Massachusetts to evaluate the benefits and costs of policies to subsidize first-generation (crop-based) biofuels in order to provide a bridge to cellulosic fuels. As a result, it is important to proceed with caution while the scientific evidence is being developed.

To date, however, the available scientific evidence suggests that cellulosic fuels will yield much greater greenhouse gas reductions per gallon of fuel than do the current crop-based fuels. If this turns out to be the case (cellulosic fuel not yet being commercially available), then the costs of government assistance per ton of greenhouse gases reduced would be much lower than for corn-based ethanol and soy-based biodiesel—and we can have more confidence that incentive policies to aid them will yield the desired environmental results in a cost-effective manner.

Economic Development Programs in Massachusetts

Massachusetts presently offers a number of financial support programs to encourage business development. Like other companies that can qualify for particular programs or benefits, biofuels companies, can and already do avail themselves of these programs. These range from grants and loans to tax credits.

General Tax Incentives for Business Investment

There are several general tax incentives intended to aid developing businesses or to encourage companies to locate in Massachusetts and/or remain here. For instance, all corporate manufacturers are eligible for an income tax credit equal to 3 percent of their qualifying investments in the state. In addition, a business that agrees to specific levels of investment and job retention in communities that are designated as Economic Target Areas can become a "certified project" through the Economic Development Incentive Program and increase its tax credit to 5 percent (Economic Opportunity Area Credit).

Companies that engage in renovation or expansion of their facilities in Economic Target Areas can also obtain exemptions on all or part of their real estate taxes for five to 20 years. These agreements, which are negotiated with municipalities, are known as Tax Increment Financing agreements. In addition to the real estate taxes, the businesses automatically receive an exemption from 100% of local "personal property taxes"—taxes on equipment in facilities.

Massachusetts also currently offers other tax advantages to companies, particularly corporate manufacturers and so-called R&D corporations. Certain equipment used by such corporations for manufacturing and R&D is exempt from sales and use taxes. In addition, the state provides highly favorable tax treatment of R&D expenses: certain costs that qualify for the federal R&D tax credit are also eligible for a 10% Massachusetts tax credit.

Finally, Massachusetts uses the "single sales factor" method of apportioning income for manufacturing corporations that are subject to tax in multiple states. For manufacturers, the state corporate excise tax applies to that portion of total net income that is determined by applying the ratio of in-state sales to total sales, without taking into account the proportion of payroll or property in the state. This can be a significant tax advantage to companies operating on a national or international scale that have or want to locate and invest in personnel and facilities in Massachusetts.

Grants

Existing state grant programs are very limited and targeted to specific business-related needs that contribute to economic development.

The Public Works Economic Development program, managed by the Executive Office of Transportation and Public Works, assists municipalities in funding transportation infrastructure that will stimulate economic development. These funds can be used for investments such as intersection improvements, which may be needed for specific development projects to move forward. Grants are awarded to municipalities, which implement the infrastructure projects.

The Workforce Training Fund, managed by the Executive Office of Labor and Workforce Development, provides resources to Massachusetts businesses and workers to train their employees. Companies that contribute to the state's unemployment insurance fund are eligible to apply for the program. Grant funds are made available to these companies provided that they match the grant value with their own contributions.

The Massachusetts Renewable Energy Trust, which is managed by the Massachusetts Technology Collaborative, provides loans and grants to support start-up renewable energy companies. Funds from the Trust, which come from charges on electric utility bills, are for the most part restricted to renewable energy technologies that produce electricity. Under limited circumstances, biofuels companies might be eligible for support from the Renewable Energy Trust.

Loans

The Emerging Technology Fund, which is managed by MassDevelopment, offers financing on favorable terms to technology companies preparing to commercialize their products or processes. Loans of up to $2.5 million are available for facilities and up to $500,000 for equipment, but may not exceed 25% of total project costs.

MassDevelopment also manages other loan programs for real estate and equipment for credit-worthy, revenue-generating companies. Real estate loans may be provided up to $3 million or 90% of property value. Equipment loans may reach $500,000, not to exceed 85% of the cost of new equipment.

MassDevelopment also offers tax-exempt bonds, which provide low interest rate loans for capital projects. Projects must be eligible for tax-exempt funding under the federal tax code. These rules impose limits on the total capital investment at a given site for a period spanning three years before the bond issue through three years after the project is completed.

Limitations of Current Tax, Grant, and Loan Assistance for Biofuels

Many companies in the rapidly growing biofuels sector are very small, early-stage enterprises. For the most part, these companies are engaged in developing new technologies, and have yet to generate revenue. In some cases, these firms enjoy substantial venture capital funding, which brings with it pressure to stretch their resources. Their needs for state support often relate to early-stage business development, research, and pilot manufacturing facilities.

Except for MassDevelopment's Emerging Technology Fund and certain sales and use tax exemptions for purchases of equipment by companies qualifying as research and development corporations, the Commonwealth's current economic development tools are limited in terms of benefits for early-stage biofuels companies. These companies are pre-profit, leaving the value of income (corporate excise) tax incentives unclaimable in the near term and loans unavailable because they are limited to credit-worthy, revenue-generating companies. The value of investment tax credits is not immediately available, but may be carried forward into the future. As for the Economic Development Incentive Program, small companies plan relatively small projects, limiting the impact of this program. Once negotiated with a municipality, the value of tax increment financing is available immediately, but that value is limited by the small increase in real estate value at the site.

Prospective Massachusetts Biofuels Policies

Cellulosic Ethanol Gasoline Tax Exemption

In November, Governor Patrick, Senate President Therese Murray, and House Speaker Salvatore DiMasi announced their support for legislation to promote the development of renewable biofuels in Massachusetts.

The bill would exempt cellulosic ethanol from the state's gasoline tax, but, since cellulosic fuel is not yet available, this would have no immediate impact on revenues. However, this preferential tax treatment would provide an incentive for companies that are engaged in efforts to make cellulosic ethanol commercially viable to bring their products to market as quickly as possible, and to do so in Massachusetts.

Based on a wide range of testimony during the Task Force deliberations, several changes to the bill as filed seem constructive. First, any fuel that qualifies should have to provide substantial reductions in greenhouse gas emissions relative to gasoline, evaluated on a lifecycle basis, including both direct and indirect impacts for both fuels being compared. Second, focusing just on ethanol is too narrow, as new technologies are currently being developed to use cellulosic feedstocks to produce non-ethanol replacements for petroleum gasoline. Therefore, the tax exemption should apply generally to cellulose-derived biofuel that is an alternative to gasoline.

> The best way for Massachusetts to drive economic development through encouraging biofuels is by nurturing and growing the already significant cluster of advanced biofuels technology companies in the state.
>
> *—Nathanael Greene, Senior Policy Analyst, Natural Resources Defense Council, testimony to the Massachusetts Advanced Biofuels Task Force, January 17, 2008*

Production Tax Credit for Massachusetts Biofuels

Direct economic development benefits to Massachusetts from biofuels come in part from displacing imports of petroleum fuel, but also from production of the fuels themselves. One way to target tax incentives for local production would be to provide a production tax credit to companies on their state income (corporate excise) taxes. Since there is little production in the state at present, such credits would only provide incentives for new production, and therefore should not materially reduce current revenues.

As most of the current biofuels activity in Massachusetts is centered on technology development, which is often pre-profit, the goal should be to incentivize early establishment of demonstration and commercial facilities in the state. This should include activities related to eventual fuel production, such as transition and growth of materials, in order to encourage development of feedstock infrastructure for advanced biofuels.

> Financial incentives for producers and consumers of biofuels should be phased out with implementation of a Low Carbon Fuel Standard, which will provide durable incentives to achieve greenhouse gas reductions and displacement of petroleum fuels at the lowest cost to consumers. However, R&D incentives may have a longer-term role in state support for the industry.

To better assist such early-stage, pre-profit firms and not-for-profit firms, the state should study making tax credits refundable (whereby companies without profits, and thus without current taxes to offset, could get tax rebates) or transferable (whereby tax credits could be sold to other firms that could use such credits to reduce their taxes). However, refundability or transferability would serve to reduce the state's tax revenues relative to then-current levels, and so would need to be evaluated carefully in light of the state's budgetary situation.

The economic benefit to the state would be even greater if this production involved Massachusetts feedstocks (as many crop-producing states have realized), and so the credit could be limited to such feedstocks. Another possible boon for Massachusetts would be to target tax benefits to the biofuel use of waste feedstocks that are not practical to recycle—and where air and water quality is not compromised—because of their local development potential, likely environmental benefits, and limited federal tax benefits compared with fuel from virgin feedstocks.

While several biodiesel production facilities are already planned for the state, suggesting the economics for these facilities are positive, production tax credits should be analyzed and considered. In addition, a credit based on the use of local feedstock could encourage the companies to shift from using sources such as soybeans or palm oil to making more use of the limited in-state sources, such as waste oils. The state could cap tax credits per facility or per company in order to control potential costs to the state budget.

As for cellulosic fuel, while Massachusetts has inherent advantages for the R&D phase of the industry, it is too early to know whether production facilities would locate here, or whether they would use in-state feedstocks (such as wood waste) without specific incentives. These questions require further research and analysis as the industry matures, but such incentives should be considered.

Tax Credit for Feedstock from Sustainably Managed Forests

Chapter 3 on biofuel feedstocks discusses the possibility of a tax credit for wood used for biofuels and biomass if it is derived from sustainably managed forests. At present, wood from land cleared for development has a market advantage over wood from managed forests, despite the greenhouse gas implications and other disadvantages of clearing new land.

To pursue such a policy, it is necessary to consider the costs and benefits of implementing state tax credits for biofuel and biomass feedstocks from in-state managed forests. This analysis should weigh the potential benefits of tax incentives for reducing greenhouse gas emissions, developing this sector of the biofuels feedstock market, and helping to maintain the

Commonwealth's working landscapes, against the cost to the state budget.

Policy Recommendations:

1. Exempt cellulosic biofuels from the state's gasoline tax, with a sunset date. An excise tax exemption will encourage fuel distributors to purchase cellulosic ethanol when available, and minimize the risk associated with investments in cellulosic biofuel companies.
2. Conduct rigorous benefit-cost analysis of prospective financial support policies for the biofuels industry, comparing benefits (including greenhouse gas reduction, employment gains, energy security, and tax revenues from economic development) with costs (including environmental impacts, state budget costs, and consumer/business expenses.)
3. Subject to state budget constraints and the lifecycle environmental and greenhouse gas criteria discussed in Chapter 2, consider the use of production tax credits and other tax incentives targeted at advanced biofuels production and commercialization, in those cases where analysis shows that projected benefits exceed costs. To better assist pre-profit and not-for-profit firms, study the implications of making tax credits refundable or transferable.
4. Subject to budget constraints, consider the costs and benefits of implementing state tax credits for the production of in-state biofuel and biomass feedstocks from sustainably managed forests and the cultivation of energy crops. Benefits to be considered should include stimulating investment in forestry and agriculture, improving the market demand and competitiveness of these feedstocks relative to residue sources of woody biomass, and maintaining and improving the Commonwealth's working landscapes. (See discussion in Chapter 3.)
5. Subject to budget constraints, authorize state funding for research in partnership with private companies and universities to improve existing technologies for converting wastes, including cranberry and other agricultural residues, to carbon-reducing, environmentally beneficial fuels. Before putting such technologies to work on a wide scale, however, subject the diversion of waste products for biofuels to full environmental and economic analysis. (See discussion in Chapter 3.)
6. Subject to state budget constraints and to lifecycle environmental and greenhouse gas criteria, create a fund that would provide grants and loans to attract advanced biofuels R&D, demonstration, and production facilities to locate in the Commonwealth in those cases where analysis shows that projected benefits exceed costs.
7. Financial incentives for producers and consumers of biofuels should be phased out with implementation of a Low Carbon Fuel Standard, since the standard will provide durable incentives to achieve greenhouse gas reductions and displacement of petroleum fuels at the lowest cost to consumers. However, R&D incentives may have a longer-term role in state support for the industry.
8. Include biofuels in priorities for state-level research on renewable energy, presumably associated with a state college or university. This educational institution should take the lead in identifying and pursuing federal funding in collaboration with biofuels companies.

Chapter 6 Endnotes

1. Note that in the federal energy law, "advanced biofuels" are those which yield lifetime greenhouse gas reductions of 50% or more compared to fossil fuels. Since estimates of these reductions are in early stages of development, we do not yet know which biofuels will qualify. In particular, soy-based biodiesel would meet this threshold if impacts on land use changes are not included or turn out to be small, but may not qualify as "advanced" if substantial land use impacts are included.
2. See Energy Efficiency and Renewable Energy Division of U.S. Dept. of Energy, http://cta.ornl.gov/bedb/biofuels/Major_Federal_Biofuel_tax_incentives.xls
3. See Section 202, Renewable Fuel Standard, in Title II of the Energy Independence and Security Act of 2007.
4. "Title II—Energy Security Through Increased Production of Biofuels, of HR6, Energy Independence and Security Act of 2007; see also "Federal Energy Independence & Security Act of 2007," Brooke Coleman, New Fuels Alliance, Jan. 31, 2007.
5. "Custom Query" extraction from database of Alternative Fuels & Advanced Vehicles Data Center, U.S. Department of Energy.
6. From database of state biofuels incentives, developed by Economic Development Research Group for Massachusetts Advanced Biofuels Task Force, version as of 2/14/2008; also see the database of the federal Department of Energy's Alternative Fuels & Advanced Vehicles Data Center.
7. Personal communication, 2/25/2008.
8. "Clean, Secure Energy and Economic Growth: A Commitment to Renewable Energy and Enhanced Energy Independence," The First Report of the Renewable Energy Task Force to Lieutenant Governor David A. Paterson, State of New York, Feb. 2008.
9. "Clean, Secure Energy and Economic Growth: A Commitment to Renewable Energy and Enhanced Energy Independence," Feb. 2008.
10. See, for example: "Ethanol and the Local Community," John Urbanchuk and Jeff Kapell, AUS Consultants and SJH Company, 2002; "The Economic Impact of Ethanol Plants in South Dakota," Randall M. Stuefen, 2005; "Contribution of Biofuels Industry to the Economy of Iowa," James Urbanchuk, 2008.
11. "The Economic Impact of the Demand for Ethanol," Michael K. Evans, Northwestern University, 1997.
12. "Contribution of the ethanol industry to the economy of the United States," John Urbanchuk, prepared for the Renewable Fuels Association, Feb. 20, 2008, page 6.
13. "Contribution of the ethanol industry to the economy of the United States," John Urbanchuk, page 5, Appendix Table 1 in the document shows national-level multipliers for economic sectors related to biofuels, and it appears that the author applied these multipliers to state-level economic output.
14. "Economic Impact of the Ethanol Industry in Minnesota," Agricultural Marketing Services Division, Minnesota Department of Agriculture, May 2003, www.mda.state.mn.us; rough employment multipliers by sector from the IMPLAN model for Massachusetts, provided by Economic Development Research Group, February 2008.
15. "Using Tax Expenditures to Achieve Energy Policy Goals," Gilbert Metcalf, Tufts University, National Bureau of Economic Research Working Paper W13753, Jan. 22, 2008.
16. "Biofuels: is the cure worse than the disease?," Richard Doornbosch and Ronald Steenblik, Round Table on Sustainable Development, Paris: Sept. 11-12, 2007, Organisation for Economic Cooperation and Development, SG/SD/RT (2007)3, Table A, page 7.
17. "Massachusetts bioenergy initiative requires restructuring to ensure energy market neutrality and cost efficiency," Doug Koplow, Earth Track, 2/28/08, page 6. Subsidies of $2/gallon of biodiesel equate to about $200/ton of CO_2 contained in petroleum diesel fuel.

Appendix A
Chapter 1: Methodology for Economic Impact Analysis

Graphic No. 1 illustrates a simplified framework to characterize the economic development impact of a given sector of the economy:

- **Direct Output** is a broad measure of the value of goods and services that can be directly attributed to the sector.
- **Indirect Output** accounts for the changes in inter-industry transactions as supplying industries respond to increased demands from the directly affected sectors.
- **Induced Output** reflects the impact of increased consumer spending resulting from income changes in the directly and indirectly affected sectors.

For simplicity, and given the preliminary nature of this analysis, economic impacts are quantified through the two most intuitive and widely adopted metrics:

- Direct Output (specifically the portion that remains in the local economy), and
- Direct Jobs Created.

Preliminary estimates for indirect and induced economic impacts are also presented based on "multiplier effects" that have been estimated (not for this specific project) using the IMPLAN[1] model in the context of Massachusetts.

For the purpose of this work, it is necessary to distinguish between two very different parts ("value chains") of the advanced biofuels sector:

- **Operational Deployment:** this includes all the activities associated with the construction and operation of advanced biofuels facilities such as engineering and construction, feedstock and biofuels production and logistics, maintenance, and operation support.
- **Technology Development:** this includes all the activities associated with research, development and commercialization of "advanced" technologies.

Graphic No. 2 (on the following page) illustrates schematically the sequence of activities (which will be referred to as segments of the value chains) that characterize both areas of activity within the sector.

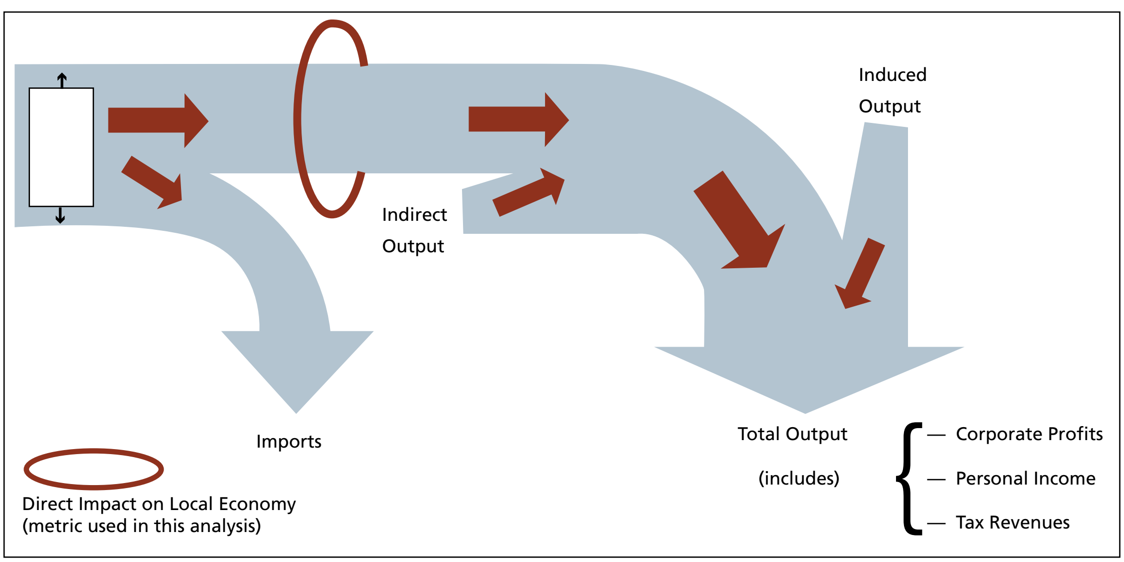
Economic benefits are broken down among the segments of each value chain. In the case of the operational deployment value chain, the segments identified in Graphic No. 2 correspond, broadly, to the following four sectors of the economy: construction; forestry, agriculture and waste management; industrial processing; and downstream oil and gas.

Scenarios for Feedstock Availability and Advanced Biofuels Production Potential

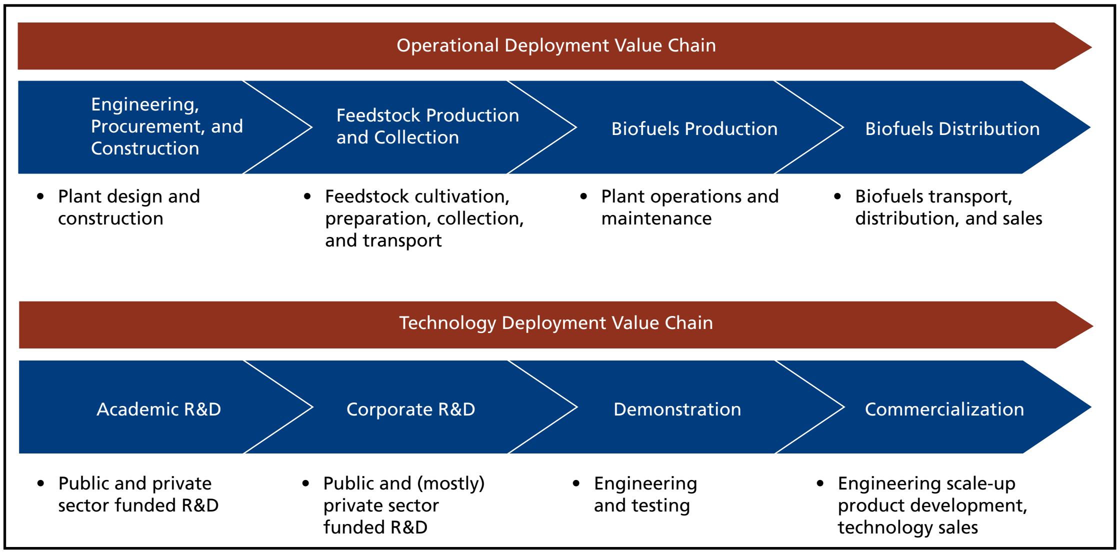
- Low Production Scenario
- General Characterization: weak policy support and marginal technology improvements
- Feedstock Supply: 1.6 MBDT per year (Million Bone Dry Tons per year) @ $20 per BDT[2]

1 The IMPLAN (Impact Analysis for Planning) model is a commonly used software package and database for estimating local economic impacts. Details at: http://edis.ifas.ufl.edu/FE168. Indirect and induced economic impacts are provided as a multiplier of direct output.

2 Price sensitivities based on ORNL study "Estimated Annual Cumulative Biomass Resources Available by State and Price", March 12, 1999.



Graphic No. 1: Characterization of Economic Impacts



Graphic No. 2: Advanced Biofuels Value Chain

- Advanced Biofuels Produced: 100 MGPY (Million Gallons of Gasoline Equivalent, or GGE, per year) at a yield of 60 gallons per dry ton

Medium Production Scenario

- General Characterization: strong policy support and technology breakthroughs; competition for feedstock with other applications (power, bio-based products)
- Feedstock Supply: 2.5 MBDT per year @ $35 per BDT
- Advanced Biofuels Produced: 200 MGPY @ 80 gallons per ton

High Production Scenario

- General Characterization: strong policy support and technology breakthroughs; limited competition for feedstock with other applications (power, bio-based products)
- Feedstock Supply: 3.7 MBDT per year @ $50 per BDT
- Advanced Biofuels Produced: 380 MGPY @ 100 gallons per ton

The following are some important considerations on biomass feedstock availability in the State as outlined in Table 2 of Chapter 1:

- These figures include some feedstocks that are currently used or recycled (such as primary mill residues and waste paper) when prices for biofuels feedstock are assumed adequate to divert this material from its current use.
- The key biomass feedstock sources in the state for biofuels production are from urban wastes. This includes categories such as construction and demolition wood, yard trimmings and the organic fractions of municipal solid waste. A high-level approach was used in this analysis, by which the collection and delivery of this feedstock to an advanced biofuels facility generates direct economic output based on the price that the biofuels facility can pay for such feedstock (regardless of how this economic value is then distributed between the different players involved such as municipalities, waste management companies, haulers, etc). However, the real implications of diverting what are currently waste streams are far-reaching and may deserve an analysis beyond the scope of the current work. For example, today municipalities pay a tipping fee for the disposal of waste to waste management firms when the material is not recycled. These transactions would be materially changed in the scenarios discussed in this analysis, with some players and sectors benefiting more than others from the economic impacts of advanced biofuels

Potential Economic Impacts of Advanced Biofuels Technology Development

The following points illustrate the potential economic impacts of advanced biofuels technology development, measured as direct output, for a range of scenarios:

Table A.1: Distribution of direct economic impacts across the operational deployment value chain			
	Distribution of Economic Impacts		
	% Value	% Incremental	% Local
Engineering, Procurement & Construction	12%	100%	30%
Feedstock Production and Collection	44%	100%	80%
Biofuels Production	38%	100%	50%
Biofuels Distribution	6%	50%	80%

- Global market for advanced biofuels by 2025: 50 BGPY (billion GGE per year)[3]
- Royalty payment: $0.05-0.08 per gallon[4]
- Percent of market for Massachusetts-based companies: 10-15%[5]
- Percent of royalty value that stays in the local economy: 50-75%[6]

Assumptions for Economic Impact Analysis

Table A.1 summarizes the assumptions that were made to calculate the incremental economic impact to Massachusetts that can be attributed to this sector.

- The majority of the value is concentrated in the "Feedstock Production and Collection" and "Biofuels Production" segments of the value chain.[7] This reflects the fact that initial capital costs for biofuels operations, even those employing advanced technologies, represent a smaller fraction of total lifecycle costs than feedstock and processing (especially when compared with other renewable energy technologies).
- Construction activities are spread out evenly over a 15 year period, although actual construction would likely be more erratic over the period in which the industry is developing.
- Other than for biofuels distribution, the economic value of the sector to the state is assumed to be entirely incremental, reflecting the fact that all fossil fuels currently used in the state are imported. By displacing imports, biofuels can partly reverse this economic outflow, "injecting" it into the local economy. For biofuels distribution, 50% of the value generated in the state is assumed to be incremental, with the remainder merely replacing lost economic activity to the state related to the distribution of displaced petroleum fuels.[8]
- The portion of direct economic activity stimulated that will remain in the state has been estimated for each segment of the value chain. This is based on common sense assumptions, as well as publicly available databases and studies.[9] One important consideration relates to biofuels production - the thermal energy as well as electricity requirements of the operation (which together may make up a substantial portion of the overall production costs) are assumed to be provided by waste biomass and do not require the use of fossil fuels.
- Direct impacts are converted into total impacts using rough estimates of the economic "multipliers" for output (1.9, meaning that for each dollar of direct spending 0.9 dollars of indirect and induced spending result) and for employment (2.3, meaning that for each direct job, 1.3 indirect/induced jobs are created). These estimates are based on a "high-level" review of economic sectors relevant to the biofuels industry.
- For construction, direct employment estimates were used to estimate economic impacts by assuming that each job is associated with $150,000 in direct spending.

3 The World Energy Outlook (published by the International Energy Agency) calls for 52 BGPY of Advanced Biofuels globally by 2030 in its Alternative Policy Case. The latest Energy Bill passed by the U.S. legislature (December 2007) contains a provision (RFS: Renewable Fuel Standard) mandating the use on 21 BGPY of Advanced Biofuels by the year 2022.

4 This represents ~2-5% of the full projected cost of (mature) Advanced Biofuels. As a royalty payment, this percentage is lower than what is typical in other sectors (for example biotechnology and pharmaceuticals), reflecting the competitive nature of energy commodity markets.

5 Massachusetts companies are currently at the forefront of technology development in the sector.

6 Some of the economic value will "leak out" of the local economy in the form of purchases of goods and services and partnerships with out-of-state technology providers and academic institutions.

7 Distribution of direct output across the value chain is based on assumed transfer prices, construction and O&M costs. Biomass cost of $50/dry ton delivered (http://bioenergy.ornl.gov/resourcedata/index.html); transportation to wholesale terminal has a value of $0.10-0.15/GGE. Yields, construction and O&M costs are based on NCI estimates and publicly available studies such as the NREL study: "Lignocellulosic Biomass to Ethanol Process Design and Economics" (http://www.nrel.gov/docs/fy02osti/32438.pdf). Value of biofuels production includes refining margins.

8 The analysis assumes that the "lost" economic value from petroleum displacement (wholesale distribution) is of $0.05-0.07/GGE, or 50% of the economic value of biofuels distribution (i.e. distribution of biofuels from the plant to the wholesale terminal is less efficient than that of petroleum). Additionally, the analysis "finishes" at the wholesale terminal: beyond that, all the value created in the retailing of biofuels merely replaces the value lost from displacing petroleum and is not incremental.

9 Value of "Feedstock Production and Collection" and "Biofuels Distribution" is assumed to remain mostly in-state given the local nature of these activities (some imports would take place in the form of equipment, etc.). EPC services are instead mostly imported as the State is assumed to have limited companies operating in this specific segment. 50% of the value generated by the conversion of biomass to biofuels is assumed to exit the economy through imports of materials (chemicals, enzymes, etc); the other 50% would remain in the local economy in the form of labor, O&M, refining margins. Figures are based on NCI estimates and previous applications of the IMPLAN model: http://www.eere.energy.gov/windandhydro/windpoweringamerica/filter_detail.asp?itemid=707

Table A.2: Direct job creation—key assumptions			
Value Chain Segments	Jobs Created Per Million Gallons/Year		
	Low	High	Comment
Engineering, Procurement & Construction	30	40	Temporary
Feedstock Production and Collection	2	2.5	Permanent
Biofuels Production	1.5	2	Permanent
Biofuels Distribution12	0.25	0.5	Permanent

Table 2 outlines job creation assumptions based on a review of publicly available literature.[10] As was done for direct output, job creation has also been estimated for each of the four segments of the operational deployment value chain. Engineering, procurement and construction jobs are considered temporary in nature (created only during the plant construction phase), while all other steps will generate permanent jobs

10 List of literature reviewed:

Daniel M. Kammen, Kamal Kapadia, and Matthias Fripp (2004) Putting Renewables to Work: How Many Jobs Can the Clean Energy Industry Generate? RAEL Report, University of California, Berkeley. Pg 10. (Corrected 2006) http://rael.berkeley.edu/old-site/renewables.jobs.2006.pdf

Urbanchuk, J.M., Kapell, J., "Ethanol and the Local Community," AUS Consultants SJH & Company, June 2002. http://www.ncga.com/ethanol/pdfs/EthanolLocalCommunity.pdf

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De La Torre Ugarte, Daniel G., Burton C. English, Chad M. Hellwinckel, R. Jamey Menard, and Marie E. Walsh. 2006. "Economic Implications to the Agricultural Sector of Increasing the Production of Biomass Feedstocks to Meet Biopower, Biofuels, and Bioproduct Demands." Department of Agricultural Economics, Draft, Research Series ? -06. http://beag.ag.utk.edu/pp/WebbioproductNRI.pdf

De La Torre Ugarte, D., M. Walsh, H. Shapouri, and S. Slinksy. 2003. "The Economic Impacts of Bioenergy Crop Production on U.S. Agriculture." U.S. Department of Agriculture, Office of the Chief Economist, Agricultural Economic Report 816. http://agpolicy.org/ppap/pp03/bio/AER816BioenergyReportTotal.pdf

Appendix B
Chapter 5: Fuel Infrastructure

Major New England Petroleum Terminals - MA				
Sources: 2007 OPIS/Stalsby Petroleum Terminal Encyclopedia and MA DOER Surveys				
Location	Terminal	Products Stored	Tank Capacity	Exchange/Throughput Partners
		Ethanol		
Braintree	Citgo Petroleum	Ethanol	176,500	ExxonMobil (XOM)
Chelsea	Gulf Oil	Ethanol	115,122	
East Boston	ConocoPhillips	Ethanol	74,585	ExxonMobil, Epic Aviation,
Revere	Global Petroleum	Ethanol	80,000	
Revere	Irving Oil	Ethanol	112,000	
Springfield	ExxonMobil	Ethanol	9,953	Texaco, XOM
			568,160	
		Regular & Premium Gasoline		
Braintree	Citgo Petroleum	Unleaded Gasoline	594,000	Hess, Gulf, Sprague,
Braintree	Citgo Petroleum	Premium	123,000	Sunoco, Valero,
Chelsea	Gulf Oil	RBOB	444,680	
Chelsea	Gulf Oil	PBOB	75,250	
East Boston	ConocoPhillips	RBOB Gasoline	303,776	New England Petroleum,
East Boston	ConocoPhillips	PBOB Gasoline	56,170	Bosfuels, Hess,
Everett	ExxonMobil	Gasoline (inc. ethanol)	627,000	Througput: Valero
Revere	Global Petroleum	Reg. Unleaded gas	635,000	
Revere	Global Petroleum	Premium gasoline	80,000	
Revere	Irving Oil	Gasoline	471,000	
Springfield	ExxonMobil	Gasoline	157,000	Gulf, Hess, Shell, Sunoco,
			3,566,876	
		On-road/Off-road Diesel		
Chelsea	Global Petroleum	Ultra low diesel	32,000	
East Boston	ConocoPhillips	Diesel	46,161	Gulf/Cumberland Farms,
Everett	ExxonMobil	ultra low sulfur diesel	185,000	Irving, Getty
Revere	Global Petroleum	ultra low diesel	100,000	
Sandwich	Global Petroleum	ultra low diesel	30,000	
Springfield	ExxonMobil	ultra low sulfur diesel	29,020	Citgo, ConocoPhillips,
Springfield	Springfield Terminals	ultra low sulfur diesel	45,238	Global Petroleum
			467,419	
		#2 Oils		
Braintree	Citgo Petroleum	#2 ultra low sulfur	198,000	
Braintree	Citgo Petroleum	#2 heating oil	306,500	
Chelsea	Global Petroleum	#2 High sulfur diesel	280,000	Global
Chelsea	Gulf Oil	#2 heating oil	369,493	none
Chelsea	Gulf Oil	#2 ultra low sulfur	126,980	
Everett	ExxonMobil	#2 High sulfur diesel	531,000	Exch: Shell (Motiva)
Everett	ExxonMobil	#2 Low sulfur diesel	0	ConocoPhillips, Gulf
New Bedford	Sprague	#2 High sulfur diesel	55,851	Global
Quincy	Sprague	#2 High sulfur diesel	220,000	ExxonMobil, Motiva
Quincy	Sprague	#2 Low sulfur diesel	91,000	
Quincy	Sprague	#2 ultra low sulfur	91,000	
Quincy	Sprague 2	#2 oil	154,000	ExxonMobil
Quincy	Sprague 2	#2 ultra low sulfur	94,000	
Revere	Global Petroleum	#2 High sulfur oil	963,000	Citgo, Getty, Sunoco
Revere	Global Petroleum	#2 Low sulfur diesel	150,000	
Revere	Irving Oil	#2 oil	155,000	?
Revere	Irving Oil	#2 Low sulfur diesel	100,000	
Sandwich	Global Petroleum	#2 High sulfur diesel	70,000	Global
Springfield	Global Petroleum	#2 oil	50,000	
Springfield	L.E. Belcher	#2 Low sulfur diesel		
Springfield	Springfield Terminals	#2 oil	50,000	
			4,055,824	
		#4, #6 & Heavy Oils		
Chelsea	Global Petroleum	#6 Residual fuels	373,000	
Everett	ExxonMobil	residual oil	505,000	
Everett	Sprague	Asphalt	429,000	
New Bedford	Sprague	Light Cycle Oil	30024	
New Bedford	Sprague	#6 Residual fuels	162,180	
Quincy	Sprague	residual oil	78,000	
Springfield	Springfield Terminals	heating oil		
			1,577,204	
		Kerosene, Jet Fuel, Additives and Other		
Braintree	Citgo Petroleum	Additives	1,469	
East Boston	ConocoPhillips	Jet A fuel	502,080	(several partners)
Quincy	Sprague	kerosene	78,000	
Quincy	Sprague	jet fuel	62,000	
Quincy	Sprague 2	caustic soda	25,000	
Revere	Global Petroleum	ultra low kero	80,000	
Springfield	L.E. Belcher	K-1 Kerosene		
Springfield	Springfield Terminals	kerosene	10,048	Global
			758,597	

Appendix C
Advanced Biofuels Task Force – Oral and Written Testimony

Alexander, Jack – Entergy

Badger, Phillip – Renewable Oil International

Bannigan, Peter – Consultant

Burke, Ted – Dennis K. Burke, Inc

Burke, Ed – Dennis K. Burke, Inc

Cahillane, James

Cawley, Jeanne

Chague, Gene – Trout Unlimited

Clarke, Tina – Clean Water Action/Mass. Climate Coalition

Coleman, Brooke – New Fuels Alliance

Cooper, Coralie – Northeast States for Coordinated Air Use Management (NESCAUM)

Crane, Dicken – Massachusetts Forest Landowners Association (MFLA)

Day, Andrew – Day's Energy Systems

Dodge, Stephen – Massachusetts Petroleum Council

Dubester, Laura – Center for Ecological Technology (CET)

Ensep, William

Federspiel, Greg – Town of Lenox

Ferrante, Michael – Massachusetts Oil Heat Council

Garjian, Michael – Vegetable Energy Group, LLC; Vee-go Energy

Garrity, Robert – Massachusetts Climate Action Network (MCAN)

Glick, Lilah – Clean Water Action

Greene, Nathanael – Natural Resources Defense Council (NRDC)

Haber, Stuart – IST Energy and Infoscitex

Harrison, Lee – Berkshire Biodiesel

Hayes, Loie – Boston Climate Action Network (BCAN)

Howe, John – Verenium Corporation

Huber, George – University of Massachusetts, Amherst

Klimchuk, Garth – NorthWinds Renewables

Koch, Arnold

Lausten, Connie – New Generation Biofuels (formerly H2Diesel)

Leschine, Susan – University of Massachusetts, Amherst

Leue, Tom – Homestead Inc

Lewis, Jonathan – Clean Air Task Force

Long, Stephen – The Nature Conservancy

Maruiello, Lauren

McDiamond, Jeremy – Environment Northeast

Mead, Joe – World Energy

Nasiff, Steve – Maine Biofuel LLC

Quinn, John – American Petroleum Institute

Quint, Eliot – Global Partners

Rennicke, Michael – Pioneer Valley Railroad

Riva, Carlos – Verenium Corporation

Rogers, John – Union of Concerned Scientists

Schoetzel, Tyson – Homestead, Inc.

Schofield, Clay – Cape Cod Commission

Schuyler, Andrew – Northeast Biofuels Collaborative

Schwarz, Robert – Peter Pan Bus Lines

Sharp, Jef – Sunethanol

Silverstein, Alan – Center for Ecological Technology (CET)

Sperling, Daniel – University of California, Davis

Spitzer, Jeremie – Greasecar Vegetable Fuel Oil

Stein, Richard – University of Massachusetts, Amherst

Swirk, Dave – Pioneer Valley Railroad

Union, Lawrence – Northeast Biodiesel

Vale, Shanna – Conservation Law Foundation

Wilke, Mike

Wright, Ben – Environment Massachusetts

Wysocki, Ted – SMF Consulting

Young, Corrine – Bionergy International

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U.S. Department of Energy Alternative Fuels and Advanced Vehicles Data Center http://www.eere.energy.gov/afdc/fuels/index.html

U.S. Department of Energy National Renewable Energy Laboratory http://www.nrel.gov/vehiclesandfuels/

U.S. Environmental Protection Agency Office of Transportation and Air Quality http://www.epa.gov/otaq/consumer/fuels/altfuels/altfuels.htm

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Appendix E
Other State Policies

Other states have active biofuels programs and incentives. For the most up-to-date descriptions and comparisons of programs see the U.S. Department of Energy's Alternative Fuels and Advanced Vehicles Data Center web page at:

http://www.eere.energy.gov/afdc/incentives_laws.html

Appendix F
Advanced Biofuels Task Force Scoping Document from Governor Deval L. Patrick, Senate President Therese Murray and Speaker of the House Salvatore F. DiMasi

There shall be a task force to study and make recommendations for legislation to promote the development of an advanced biofuels industry in the Common-wealth. The task force shall develop a strategic framework to accelerate the development and deployment of commercially viable advanced biofuels, and facilitate expansive biofuel research throughout the Commonwealth. Said strategic framework shall include, but shall not be limited to, the following: (i) promoting infrastructure for cellulosic feedstock delivery to processing plants and for the distribution of ethanol to motor fuel distributors; (ii) developing a regulatory and legislative framework to expedite siting and permitting of ethanol or bio-diesel manufacturing or distribution facilities within the Commonwealth; (iii) analyzing the energy and environmental lifecycle of advanced biofuels; (iv) fostering the development of a market for energy crops; (v) tax incentives and research grants to identify and promote the development of domestic feedstocks and technologies necessary to manufacture advanced biofuels in the commonwealth, and (vi) regulatory and legislative actions intended to promote increased reliance on ethanol as an ingredient for fuel in Massachusetts.

The task force shall also consider existing barriers to the development and implementation of advanced biofuels as an increasing part of the fuel mix, legislative or administrative actions to overcome those barriers, and the availability of federal grants to assist in the development of advanced biofuels. The task force shall be comprised of three members of the Senate, two appointed by the president of the Senate and one appointed by the minority leader of the Senate; three members of the House, two appointed by the speaker of the House and one appointed by the minority leader of the House; and three members appointed by the Governor, one of whom shall be the Secretary of Energy and Environmental Affairs or his designee, who shall chair the task force, and one of whom shall be employed by a company that works in the field of advanced biofuels. In developing its recommendations, the task force shall consult with the New Fuels Alliance and at least one distributor of petroleum products domiciled in Massachusetts. The task force shall hold no fewer than four hearings, at least one of which shall be in western Massachusetts and at least one of which shall be in southeastern Massachusetts. The task force shall file a report of its findings and recommendations with the Governor and with the clerks of the House and Senate no later than March 31, 2008.

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Glossary of Terms

Advanced or second-generation biofuels – defined in the new federal energy law as any fuel, except corn-based ethanol, that yields at least a 50% lifecycle reduction in greenhouse gas emissions compared with petroleum fuel. Advanced biofuels are generally fuels that are not made from food crops, but are instead derived from cellulosic-based or biomass materials.

ASTM – ASTM International, originally known as the American Society for Testing and Materials, a private-sector standards development organization that develops voluntary technical standards for materials, products, systems and services.

Biodiesel – a fuel made by chemical processing of vegetable oils and other fats. It can be used either in pure form or as an additive blended with petroleum-based diesel fuel, and contains about as much energy per gallon as petroleum diesel. At low blends, such as 5% (called B5), and possibly at higher blends, it can be used in both vehicle engines and heating equipment without requiring equipment changes.

Biofuel – a fuel produced from any organic matter that is available on a renewable or recurring basis, including plant biomass, vegetable oils and other non-hazardous waste materials such as greases. Types of biofuels include ethanol, biobutanol, biodiesel, hydrogenation-derived fuels, and biogas.

Biomass – any biological materials; generally solids such as cellulosic organic materials, plant or algal matter, animal wastes or byproducts, agricultural crops or crop byproducts and wood materials or wastes.

Biorefinery – any facility that produces a product such as fuel, heat, or power from bio-based materials.

Cellulosic fuels – liquid fuel, such as cellulosic ethanol, derived from plant materials that are generally inedible, consisting largely of lignin, cellulose and hemicellulose – the main constituents of cell walls in most plants. For example: the stalks of food crops that remain after the edible portions have been removed; or post-consumer, commercial organic residues that are available on a renewable or recurring basis. Once they are commercially available, cellulosic fuels are expected to yield substantially better lifecycle reductions in greenhouse gas emissions than first-generation biofuels such as corn-based ethanol. In the federal energy law, cellulosic fuel must reduce greenhouse gas emissions by at least 60% in comparison with petroleum fuel.

Ethanol – a form of alcohol, also known as ethyl alcohol, that can be derived from crops such as corn and sugar via fermentation. In the United States, almost all ethanol is derived from corn, while in Brazil the main source is sugar. Providing about 30% less energy per gallon than gasoline, it is most commonly used in the United States in a blend containing 10% ethanol and 90% gasoline, called E10, which helps to reduce air pollution and is sold as regular gasoline.

Feedstock – material that is used as a source for conversion into a fuel, such as corn, soy, wood, switchgrass, or organic waste materials.

First-generation biofuels – generally, non-petroleum fuels derived from food crops, especially ethanol derived from corn. In the federal energy law passed in December 2006, they are defined as fuels that yield less than a 20% reduction in greenhouse gas emissions over their lifecycles, in comparison with the petroleum fuel that they would replace.

Greenhouse gas emissions – emitted gases that trap heat in the atmosphere, thereby contributing to global climate change. Carbon dioxide, or CO_2, is the predominant greenhouse gas, produced by the combustion of any carbon-containing material, including both fossil fuels (oil, gas, coal) and renewable organic materials such as wood or ethanol. Other greenhouse gases include methane and nitrous oxide.

Lifecycle greenhouse gas emissions – in the context of this report, emissions which occur not only when a fuel is burned, but which result from the entire lifecycle of creating and using a fuel. For petroleum fuel, this would include exploring for oil, drilling and extracting oil, and transporting it to end use points. For biofuels, it includes emissions from manufacturing and running farm machinery, producing fertilizers and pesticides, and processing crops into ethanol or biodiesel. Recently, it is also being defined to include indirect impacts that take place if the use of crops for fuel instead of food causes conversion of additional forest or grassland into crop land.

Low Carbon Fuel Standard (LCFS) – a Low Carbon Fuel Standard is currently being developed in California, where it was instituted by executive order of the governor as one part of achieving the state's overall commitment to reduce greenhouse gas emissions. The LCFS mandates that the "carbon intensity" – lifecycle greenhouse gas emissions per unit of energy delivered – of vehicle fuel in California be reduced 10% by 2020. All methods of powering vehicles would be eligible for the LCFS – not only liquid fuels, but also all-electric vehicles, plug-in hybrids, and hydrogen fuel cells. The LCFS would not require every gallon of fuel used in the state to have 10% lower carbon content, but instead that the average of all fuel used in the state would be 10% lower. Thus, a fuel distributor could meet the requirement by selling some cellulosic ethanol while continuing to sell mostly gasoline, or by buying "carbon credits" from other distributors who have reduced their average emissions by more than 10%.

Renewable – a resource that can be regrown, in contrast to fossil fuels which are in fixed supply (making them non-renewable).

Advanced Biofuels Task Force

Commonwealth of Massachusetts

Deval L. Patrick, Governor

Therese Murray, Senate President

Salvatore F. DiMasi, Speaker of the House

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